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Ion Exchange Kinetics Testing with SRF Resin

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April 2012

Pacific Northwest NATIONAL LABORATORY

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Test Specification: 24590 PTF-TSP-RT-09-002, Rev. 0
Test Plan: TP-WTPSP-002, Rev. 2.0
Test Exceptions: 24590-PTF-TEF-RT-10-00001, Rev. 0, 24590-PTF-TEF-RT-10-00002, Rev. 1, and 24590-PTF-TEF-RT-11-00001, Rev. 0
R&T Focus Area: Pretreatment
Test Scoping Statement: None

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Pacific Northwest National Laboratory
Richland, Washington 99352

Completeness of Testing

This report describes the results of work and testing specified by Test Specification, 24590-PTF-TSP-RT-09-002, Rev 0 and Test Plan TP-WTPSP-002, Rev. 2.0. The work followed the quality assurance requirements outlined in the test specification and test plan. The descriptions provided in this report are an accurate account of both the conduct of the work and the data collected. Test plan results are reported. Also reported are any unusual or anomalous occurrences that are different from expected results. The test results and this report have been reviewed and verified.

Approved:

D E Kurath ______________________ 4/17/12 __________

Dean E. Kurath, Manager
WTP R&T Support Project

Date

Testing Summary

Ion exchange using the Spherical Resorcinol-Formaldehyde (SRF) resin has been selected by the U.S. Department of Energy's Office of River Protection (DOE-ORP) for use in the Pretreatment Facility (PTF) of the Hanford Tank Waste Treatment and Immobilization Plant (WTP) and for potential application in an at-tank deployment. Numerous studies have shown the SRF resin to be effective for removing ^{137}Cs from a wide variety of actual and simulated tank waste supernatants (Adamson et al. 2006; Blanchard et al. 2008; Burgeson et al. 2004; Duignan and Nash 2009; Fiskum et al. 2006a; Fiskum et al. 2006b; Fiskum et al. 2006c; Fiskum et al. 2007; Hassan and Adu-Wusu 2003; King et al. 2004; Nash et al. 2006). Most of the prior work at the Pacific Northwest National Laboratory (PNNL) focused primarily on the loading behavior for 4 to 6 M Na solutions at 25°C to 45°C and the eluting behavior of the loaded SRF resin with virgin 0.5 M HNO_3. Recent proposed changes to the WTP ion exchange process baseline indicate that loading may include a broader range of sodium molarities (2 to 8 M) and higher temperatures (50°C) to alleviate post-filtration precipitation issues. In addition, elution will likely utilize variable-strength recycled nitric acid containing trace amounts of ^{137}Cs as reported by Brown et al. (2011).

This report discusses the ion exchange loading kinetics testing activities in accordance with the test plan[a] prepared and approved in response to the Test Specification 24590-PTF-TSP-RT-09-002, Rev. 0 (Lehrman 2010). This testing focuses on broadening the data range of SRF resin testing under the conditions expected with the new equipment and process changes. These changes include a broader range of sodium molarities (2 to 8 M) and higher temperatures that may be required to alleviate post-filtration precipitation issues.

Objectives

The test objectives were to:

- Determine the impact of 2 M to 8 M sodium, Na/Cs ratio, and total hydroxide on Cs ion exchange kinetics and loading of the SRF resin.
- Determine the impact of multiple moderate temperature loading cycles on Cs ion exchange kinetics and loading of the SRF resin.
- Determine the impact of temperature on Cs ion exchange loading of the SRF resin during extended (>30-day) exposure to flowing waste simulants.
- Determine if the presence of organic compounds in the waste stream has an effect on the loading kinetics and overall Cs loading of the SRF resin.
- Determine the impact of free hydroxide in the waste simulant on the Cs loading kinetics and loading performance of the SRF resin.
- Determine the impact that long-term exposure to 0.5 M HNO_3 at higher temperature (>45°C) has on the subsequent Cs loading of the SRF resin.

(a) RL Russell. 2010. *Cesium Ion Exchange Simulant Testing in Support of M6*. TP-WTPSP-002, Rev. 2.0, Pacific Northwest National Laboratory, Richland, Washington.

Table S.1 provides the objectives that applied to the ion exchange loading kinetics testing task. Other objectives identified in Test Plan TP-WTPSP-002[a] did not apply to this activity but instead apply to the small-column elution testing task that was discussed in WTP-RPT-210 (Brown et al. 2011).

Table S.1. Summary of Test Objectives and Results

Test Objective	Objective Met?	Discussion
• Determine the impact of 2 M to 8 M sodium, Na/Cs ratio, and total hydroxide on Cs ion exchange kinetics and loading of the SRF resin.	Yes	Kinetic tests were performed with simulants with varying Na concentrations, OH concentrations, and Na/Cs ratios using SRF resin in a column. It was found that the kinetics and Cs loading were not affected by these variables. However, it was found that feed flow velocity did affect the kinetics and Cs loading with them being directly related. These results are discussed in Section 4.1.
• Determine the impact of multiple moderate temperature loading cycles on Cs ion exchange kinetics and loading of the SRF resin.	Yes	The columns were loaded with a 5 M Na feed initially and then cycled through several loading and elution tests. After a total of four cycles, the column was loaded with the same 5 M Na feed as used initially. The level of Cs loading on the resin was then compared. Moderate temperature cycling did not affect the loading kinetics. However, the overall Cs loading was impacted at 60°C and above. These results are discussed in Section 4.1.
• Determine the impact of temperature on Cs ion exchange loading of the SRF resin during extended (>30-day) exposure to flowing waste simulants.	Yes	Columns were held at varying temperatures from 45°C to 75°C for 30 days with feed being passed through them. Samples were taken periodically to assess the loading of the resin. It was found that the loading capacity of the resin was significantly reduced above 45°C and did not appear to load above 60°C. The resin disintegrated at 75°C and partially disintegrated at 65°C causing the column to plug in both tests. These results are discussed in Section 4.2.
• Determine if the presence of organic compounds in the waste stream has an effect on the loading kinetics and the overall Cs loading of the SRF resin.	Yes	When compared to a reference column, which was tested under the same conditions and feed without the organics, the presence of organics did not affect the loading capacity or kinetics of the loading at 45°C. This indicates that organics should not be a factor during ion exchange operation for the WTP. These results are discussed in Section 4.4.
• Determine the impact of free hydroxide in the waste simulant on the Cs loading kinetics and loading performance of the SRF resin.	Yes	Kinetic tests were performed with simulants with varying OH concentrations using SRF resin in a column. It was found that the kinetics and Cs loading were not affected by OH concentration. These results are discussed in Section 4.1.

(a) RL Russell, GN Brown, and RA Peterson. 2010. *Cesium Ion Exchange Simulant Testing in Support of M-6.* TP-WTPSP-002, Rev 1.0, Pacific Northwest National Laboratory, Richland, Washington.

Test Objective	Objective Met?	Discussion
• Determine the impact that long-term exposure to 0.5 M HNO_3 at higher temperature (>45°C) has on the subsequent Cs loading of the SRF resin.	Yes	Small samples were contacted with 0.5 M HNO_3 for 70 days at 25°C, 45°C, and 55°C. One sample was contacted with de-ionized water for 70 days at 25°C as a reference. It was found that the loading capacity of the resin afterwards was significantly lowered at 45°C while the resin held at 55°C dissolved and could not be loaded. The resin held at 25°C showed no effect in the subsequent loading. These results are discussed in Section 4.3.

Test Exceptions

The test exceptions that were applicable to Test Plan TP-WTPSP-002 are presented in Table S.2.

Table S.2. Test Exceptions

Test Exception Number	Description of Test Exception
24590-PTF-TEF-RT-10-00001, Rev 0	This test exception was received from Bechtel National, Inc. (BNI) on September 13, 2010. The primary temperature selected for testing was 45°C. However, the operating temperatures have been changed in the design of the ultra-filtration process (UFP) and Cs ion exchange process. Temperatures were added and changed to include 50°C to determine cesium removal performance impacts based on these design updates.
24590-PTF-TEF-RT-10-00002, Rev 1	This test exception was received from BNI on September 25, 2010. The kinetics testing described in the test plan[(a)] had an elution flow rate of 1.4 bed volumes (BV)/hour. It was determined that the lowest accurate flow rate that the pumps can support was 2.8 BV/hour. It was determined that using 2.8 BV/hour would not impact the test objective, so it was changed. It was also determined that the Cl concentration for stock solutions 8C20, 8D40, and 8E40 were above the solubility limits. For these stock solutions, the Cl was eliminated and the NO_3 concentration was increased to maintain the Na concentration.
24590-PTF-TEF-RT-11-00001, Rev 0	This test exception was received from BNI on March 11, 2011. Results for the testing of Cs kinetic load tests indicated that further investigation was required. Further work was added to identify the potential precipitates and particles observed during the 65°C and 75°C long-duration runs. The highest temperature to complete the 30-day duration test without issues was 50°C. Therefore, tests at 55°C and 60°C were added also.

(a) RL Russell. 2011. *Cesium Ion Exchange Simulant Testing in Support of M6*. TP-RPP-WTPSP-002, Rev. 2.0, Pacific Northwest National Laboratory, Richland, Washington.

Results and Performance Against Success Criteria

The Research and Technology (R&T) success criteria for achieving the test objective is discussed in Table S.3. Only the success criteria for the ion exchange loading kinetics testing task are displayed in the table. The success criteria for the portion of the small-column elution testing of Test Plan TP-WTPSP-002 are not shown in this table and were discussed in WTP-RPT-210 (Brown et al. 2011).

Table S.3. Success Criteria Ion Exchange Loading Kinetics

List Success Criteria	Explain How the Tests Did or Did Not Meet the Success Criteria
1) Develop empirical information that allows determination of the effect of initial Na ion concentration, equilibrium Na/Cs ratio, and total OH on the apparent Cs diffusivity in the ion exchange media.	This success criterion was met. The columns were loaded with various compositions of simulants for 10 hours. The level of Cs in the solution was periodically measured and then compared. It was found that none of these variables played a role in the kinetics of the Cs loading under these conditions. However, it was found that feed flow velocity did affect the kinetics and Cs loading with them being directly related.
2) Develop empirical information that allows determination of the effect of multiple moderate temperature loading cycles on the Cs kinetics and loading of the SRF resin.	This success criterion was met. The columns were loaded with a 5 M Na feed initially and then cycled through several loading and elution tests. After a total of four cycles the column was loaded with the same 5 M Na feed as used initially. The level of Cs loading on the resin was then compared to determine the effect of these variables. The kinetics of loading was not affected after moderate temperature cycling; however, in the 60°C and above tests the overall loading was impacted.
3) Develop empirical information that allows determination of the impact of temperature on Cs loading of the SRF resin during extended (>30-day) exposure to flowing waste simulants.	This success criterion was not met. Most of the extended run tests that were intended to run for 720 hours were aborted after ~336 hours due to resin degradation and column plugging. Columns were held at varying temperatures from 45°C to 75°C for 14 to 30 days with feed being passed through them. Samples were taken periodically to assess the loading of the resin. It was found that the loading capacity of the resin was significantly reduced above 45°C and did not appear to load above 60°C. The resin also disintegrated at 75°C until left with minimal residue and partially disintegrated at 65°C causing the column to plug in both tests.
4) Measure the Cs removal performance (resin Cs load capacity and Cs removal kinetics) after a high organic content feed is used on the resin.	This success criterion was met. The column was loaded with a high organic feed for 10 hours and then eluted for 10 hours. There was no difference in the loading or eluting capacity of the resin when processing high organic feed.
5) Develop empirical information that allows determination of the effect of free OH on the Cs kinetics and loading of the SRF resin.	This success criterion was met. Kinetics tests were performed with simulants with varying OH concentrations using SRF resin in a column. It was found that the kinetics and Cs loading were not affected by OH concentration.
6) Provide Cs load performance data collected after the resin has been stored at variable temperatures including (>45°C) in 0.5 M HNO_3.	This success criterion was met. Several samples of resin were placed in 0.5 M HNO_3 and held at 25°C, 45°C, or 55°C for 70 days. One set of samples was held at 25°C in de-ionized water (DIW) for 70 days as a control batch. Then each sample was removed and loaded with Cs in a batch contact at 25°C for 24 hours with periodic samples taken to assess the level of Cs loading. The results showed that the acid did not seem to affect the loading of the resin at 25°C. However, at 45°C the kinetics of the resin loading were significantly reduced with a lower overall loading and at 55°C the resin had completely disintegrated and was unable to be loaded for a comparison.

Quality Requirements

The PNNL Quality Assurance (QA) Program is based on the requirements defined in the U.S. Department of Energy Order 414.1D, *Quality Assurance,* and 10 CFR 830, *Energy/Nuclear Safety Management*, and Subpart A—*Quality Assurance Requirements* (a.k.a. the Quality Rule). PNNL has chosen to implement the following consensus standards in a graded approach:

- ASME NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility Applications*, Part 1, Requirements for Quality Assurance Programs for Nuclear Facilities.
- ASME NQA-1-2000, Part II, Subpart 2.7, *Quality Assurance Requirements for Computer Software for Nuclear Facility Applications*.
- ASME NQA-1-2000, Part IV, Subpart 4.2, *Graded Approach Application of Quality Assurance Requirements for Research and Development*.

The procedures necessary to implement the requirements are documented through PNNL's "How Do I…?" (HDI[a]).

The Waste Treatment Plant Support Project (WTPSP) implements an NQA-1-2000 Quality Assurance Program, graded on the approach presented in NQA-1-2000, Part IV, Subpart 4.2. The WTPSP Quality Assurance Manual (QA-WTPSP-0002) describes the technology life cycle stages under the WTPSP Quality Assurance Plan (QA-WTPSP-0001). The technology life cycle includes the progression of technology development, commercialization, and retirement in process phases of basic and applied research and development (R&D), engineering and production and operation until process completion. The life cycle is characterized by flexible and informal quality assurance activities in basic research, which becomes more structured and formalized through the applied R&D stages.

The work described in this report has been completed under the QA technology level of Applied Research. WTPSP addresses internal verification and validation activities by conducting an Independent Technical Review of the final data report in accordance with WTPSP's procedure QA-WTPSP-601, Document Preparation and Change. This review verifies that the reported results are traceable, that inferences and conclusions are soundly based, and that the reported work satisfies the test plan objectives.

Section 5.0 is for information only. The work described in this section uses a commercially available software program (VERSE-LC) in order to model the kinetic experiments. However, the software was not added to the approved software list under the QA program and thus, despite the technical validity of the work presented in this section, must be considered for information only.

R&T Test Conditions

This report summarizes the ion exchange removal of Cs from a simple waste simulant using Microbeads SRF resin, Lot 5E-370/641. The resin was sub-sampled from existing stock that had been stored under N_2 at PNNL for more than 4 years in the H^+-form. The resin was bulk pretreated with de-ionized (DI) water, 1 M NaOH, and 0.5 M HNO_3 to cycle between Na^+ and H^+-forms. The resin was

(a) System for managing the delivery of PNNL policies, requirements, and procedures.

then further pretreated in the column with another acid/base cycle prior to simulant loading. Dry resin density was determined by drying duplicate samples under vacuum at 50°C to constant mass.

Several columns of SRF resin were loaded with various simple simulants containing various amounts of Cs, Na, and Al, partially eluted with 3 BV 0.5 M HNO_3 and then eluted with 25+ BV of 0.25 M HNO_3 solution.

All test conditions delineated by the test plan and test exceptions were met. A summary of test conditions is provided in Table S.4.

Table S.4. R&T Test-Condition Summary

List R&T Test Conditions	Were Test Conditions Followed?
1) Ion Exchange Loading Kinetics Tests	
Small-column ion exchange loading tests were performed near prototypic flow conditions with feed recycle until equilibrium loading was achieved in order to evaluate cesium uptake kinetics. The scoping tests included a fractional factorial experimental design and the various simulant feed compositions. They:	A series of column loading and elution cycles were completed as detailed in Table 3.3. The composition of the simulants used is shown in Table 3.1. The general column processing steps (e.g., pretreatment, loading, feed displacement, rinsing, elution, rinsing, regeneration) are described in Table 3.2.
• Examined the impact of linear load velocity (4, 6, 8 cm/min) • Examined the impact of initial Na concentration (2, 5, 8 M) • Examined the impact of initial Na/Cs ratio (1.4E+05, 2.1E+05, 2.8E+05 mol/mol) • Examined the impact of initial Na/OH ratio (2.0, 3.0, 4.0 mol/mol) • Examined the impact of high free OH on resin degradation during extended solution flow using elevated temperature (45°, 50°, 55°, 60°, 65°, 75°C) to derive a degradation rate equation.	The ion exchange columns were loaded with simulant feed solution at temperatures between 25±2°C and 75±2°C. The solution was processed at various flow velocities, initial Na concentrations, initial Na/Cs ratios, free OH concentrations, and initial Na/OH ratios as shown in Table 3.3 for the 10 h of loading. Following loading, the feed solution was displaced with 7.5 BVs of 0.1 M NaOH, rinsed with 7.5 BVs of DI water, and the resin was neutralized with 3 BVs of 0.5 M HNO_3 at 3 BV/h as is outlined in Table 3.2.
If filtration was performed prior to ion exchange, the filtration temperature was to be 40°C. If precipitation was observed in simulant samples before or after ion exchange, the Process Technology lead was to be notified and the observations and sample storage conditions were to be recorded in the final test report. Samples where precipitation was observed were to be saved until disposition of the sample was agreed upon with the Process Technology lead.	Filtration was not performed before the ion exchange. Precipitation was observed in the initial 8 M Na simulant solutions after testing and during the long-term testing. The Process Technology lead was notified and observations were made. Samples were also saved.
The crystalline precipitate observed in the feed solution that was heated to 75°C was evaluated with a polarized light microscope (PLM) to identify the crystal. Photographs of the bottle containing the precipitate and photographs of the magnified precipitate were taken.	The crystalline precipitate was evaluated with PLM to identify the crystals and photographs were taken as shown in Section 4.2.

The filtered and dried solids from the water solutions used to rinse the wet beads and white residue from the glass column wall in columns C and B were evaluated with a PLM and with a scanning electron microscope (SEM).	The filtered, dried solids from the water solutions used to rinse the wet beads and white residue from the glass column wall in columns C and B were evaluated with PLM and SEM as shown in Section 4.2.
The sludge/particulates observed in the tubing during the 75°C and 65°C runs were evaluated with a PLM and with a SEM.	All of the other particulates that were observed were also evaluated with PLM and/or SEM as shown in Section 4.2.

List R&T Test Conditions	Were Test Conditions Followed?
The resin from the kinetics tests were compared using SEM to the fresh resin to see if there were any notable changes in the resin with variations in process conditions and compositions. Solutions and spent resin materials from the kinetics tests were reserved until concurrence for disposal was received from the WTP Process Technology lead.	Pictures of the used resin and the fresh resin were taken using the SEM to compare. We have not disposed of the solutions and spent resin materials from the kinetics tests.
Upon completion of these scoping tests, a surface response factorial design was developed based on the fractional factorial design. This surface response design evaluated the two parameters determined to have the most significant effect on resin kinetics. This design was provided to BNI personnel for review and approval. Approval was to be provided by the BNI point of contact, prior to additional surface response factorial testing.	These test conditions were replaced with a test exception and therefore were not performed.
The results from these tests were used to assess the impact of process conditions on the diffusivity and film mass transfer coefficient. Tests performed at varying axial velocity provided a measure of the impact of the film mass transfer coefficient. Tests performed at varying Na concentrations and Cs/Na ratios provided a measure of the impact of the diffusivity on ion exchange performance. These results were analyzed to evaluate the film mass transfer coefficient and the diffusivity.	The results were analyzed using the VERSE-LC model system. The final simulation results (the parameters that gave the best fit as measured) are shown in Section 5.4.
Preliminary results of testing were transmitted to WTP for modeling of test column performance by WTP personnel using ion exchange column modeling software.	All of the preliminary results were transmitted to WTP.
2) Ion Exchange Interaction with Organics Tests	
In order to evaluate the effect that organic compounds have on Cs ion exchange of the SRF resin, a single kinetics test was completed and compared to Test-1-A-1. The organics scoping test consisted of a single solution containing 5 M Na, 1.67 M OH, 2.08E+05 initial Na/Cs ratio and a wide variety of organic compounds. The solution containing the inorganic and organic compounds was loaded at 45°C for 10 h at 6 cm/min. The	The impact of organics test was performed using the simulant ID 5B17 listed in Table 3.1 with the organics listed in Tables 3.5 and 3.6 added. The simulant solution was prepared in the same manner with the organics added at the end to make 250 mL.

List R&T Test Conditions	Were Test Conditions Followed?
experimental conditions were identical (except the organic compounds) to Test-1-A-1.	
• Examined the impact of organic compounds in the loading solution. The organics added are the same organics that were previously tested (Nash 2004) in Savannah River National Laboratory (SRNL) resin testing (Table 8 of SCT-M0SRLE60-00-110-00027, Rev. B) along with antifoam and its degradation products. The antifoam was added at a concentration of 2000 ppm, along with 1000 ppm of each of the degradation products. The simulant spiked with organics was filtered with a 0.1 micron filter prior to contacting the resin.	The impact of organics test was performed using the simulant ID 5B17 listed in Table 3.1 with the organics listed in Tables 3.5 and 3.6 added. The antifoam agent was added at a concentration of 2000 ppm and the antifoam degradation products were added at 1000 ppm. After adding the organics, the solution had a significant amount of gelatinous material present. Therefore, it was filtered through a KimWipe™ paper to remove this before filtering through a 0.1 µm filter to remove any undissolved solids still present.
• After the organics were filtered, total inorganic carbon/total organic carbon (TIC/TOC) analysis was used to estimate the quantity of organic carbon that passed through the 0.1 micron filter and contacted the resin.	A TIC/TOC analysis of the feed was performed both before filtering and after filtering had occurred. The organics did not appear to have any impact in the loading. However, the antifoam created a slightly gelatinous solid in the solution.
If filtration was performed prior to ion exchange, the filtration temperature was to be 40°C. If precipitation was observed in simulant samples before or after ion exchange, the Process Technology lead was to be notified and the observations and sample storage conditions were to be recorded in the final test report. Samples where precipitation was observed were to be saved until disposition of the sample was agreed upon with the Process Technology lead.	No precipitation was observed after simulant preparation and filtration.
3) Elution Temperature Effect on Resin	
Three small (<10 mL) batches of fresh SRF resin were each contacted with 0.5 M HNO_3 for 70 days. One of the three batches was stored at ~25°C, one batch was stored at ~45°C, one batch was stored at ~55°C, and a fourth batch (fresh resin that was not exposed to HNO_3) was stored at ~25°C as a control sample. After 70 days, each of the four batches of SRF resin were converted to the Na form, and then contacted with the same Cs loading solution from Test-1-A-1. The identical conditions facilitated a direct comparison.	Fresh SRF resin was contacted with 0.5 M HNO_3 while continually mixing on a shaker for 70 days at three different temperatures-~25°C, 45°C, 55°C. A fourth set of samples of fresh resin was contacted with DI water at ~25°C as a control sample while continually mixing on a shaker for 70 days. A ratio of 1:100 was used for all resin and solution mixtures (0.1 g resin in 10 mL solution). After 70 days, the resin was removed from the acid (or DI water), rinsed three times for 30 minutes each time with 10 mL of DI water and then contacted twice with 10 mL of 0.5M NaOH, once for an hour and then once for 24 hours, to convert the resin to the Na form. After the 24-hour NaOH contact, the resin was removed and contacted with 25 mL of the cesium loading solution (5 M Na, 1.67 M OH, and 2.4E-05 M Cs). The

List R&T Test Conditions	Were Test Conditions Followed?
	experimental matrix is shown in Table 3.4. Analytical samples were collected at 0, 1, 4, 10, and 24 hours to define the Cs uptake curve by filtering ~10 mL of the supernate from the sample bottle using a 0.45 µm disposable syringe filter and placing it in the specified sample vial. Each test was performed in duplicate with a blank sample taken at 0 and 24 hours. Simulant samples were submitted to SwRI for analysis. Analysis methods included ICP-MS for Cs, ICP-OES for Na, and Al, IC for anions and OH analysis.
If filtration is performed prior to ion exchange, the filtration temperature is to be 40°C. If precipitation is observed in simulant samples before or after ion exchange, the Process Technology lead is to be notified and the observations and sample storage conditions are to be recorded in the final test report. Samples where precipitation is observed are to be saved until disposition of the sample is agreed upon with the Process Technology lead.	No filtration was performed prior to ion exchange. No precipitation was observed. However, the resin totally disintegrated at 55°C.
Data from this testing will be analyzed to determine the impact of elevated elution temperature on resin degradation and performance.	The resin was loaded and the Cs loading curve was analyzed using the ICP-MS data. It was determined that elevated elution temperature did have a significant impact on the resin degradation and performance. The resin degraded so badly at 55°C that a loading curve was unable to be obtained.

Simulant Use

The small-column kinetics loading testing task was performed using several non-radioactive aqueous solutions for loading of the SRF resin. These simple simulant compositions were provided by BNI as documented in Test Specification *RF Resin Cesium Removal with Expanded Load and Elution Conditions*.[(a)] The Na, Cs, Al, and OH concentrations were within the ranges expected for aqueous waste feeds to the PTF. The nominal Na concentration was selected to be 5 M, and the nominal Cs concentration was selected to be 2.4E-05 M. No K was included in the simulant. The nominal free OH concentration was selected to be 1.55 M, and the Al concentration was selected to be 0.115 M, approximately 90% of the solubility limit. The simulant was not selected to represent any particular Hanford tank waste type.

(a) S Lehrman and M Thorson. 2010. *RF Resin Cesium Removal with Expanded Load and Elution Conditions.* 24590-PTF-TSP-RT-09-002, Rev 0, Bechtel National, Inc., Richland, Washington.

Discrepancies and Follow-on Tests

Most of the extended run tests that were intended to run for 720 hours were aborted after ~336 hours due to resin degradation and column plugging.

It was found that the loading capacity of the resin was significantly reduced above 45°C and did not appear to load above 60°C. The resin also disintegrated at 75°C until left with minimal residue and partially disintegrated at 65°C causing the column to plug in both tests. Therefore, it is recommended that the temperature effect on the resin loading and degradation be examined more carefully and bracketed closer so that the upper resin use temperature may be known.

It is also recommended that a simulant containing K be tested so that the effect of K on the Cs loading of the resin can be determined.

There were some limitations to using the VERSE-LC model that could be mitigated with additional time. First, the interface of the software was not conducive to a more automated minimization routine. This could be automated to find a minimum using any standard optimization routine, but would have to involve a second software platform. Second, the accuracy of the results could also be improved with better input data, in particular a good estimate of the maximum solute capacity for cesium and accurate measurement of the physical properties of the solution (viscosity and diffusion coefficients in particular). Third, a more complex model could be built that incorporates some of the ignored species such as Rb^+, K^+, and Na^+ that compete with Cs^+ for adsorption sites on the resin.

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Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
BNI	Bechtel National, Inc.
BV	bed volumes
CSTR	Continuously Stirred Reactor
DIW	de-ionized water
DOE	U.S. Department of Energy
EDS	energy dispersive scattering
FFPM	perfluorinated elastomer
GGRF	ground gel resorcinol-formaldehyde
HDI	How Do I
HLW	high-level waste
IC	ion chromatography
ICP	inductively coupled plasma
MS	mass spectroscopy
NA	not applicable
OES	optical emission spectroscopy
ORP	Office of River Protection
PLM	polarized light microscopy
PNNL	Pacific Northwest National Laboratory
PTF	Pretreatment Facility
PTFE	polytetrafluoroethylene
PVDF	polyvinylidene fluoride
QA	quality assurance
R&D	research and development
RF	resorcinol-formaldehyde
RMSE	root mean square error
RPP	River Protection Project
R&T	research and technology
RV	resin volume
SEM	scanning electron microscopy
SRF	spherical resorcinol formaldehyde
SRNL	Savannah River National Laboratory
SwRI	Southwest Research Institute
TIC	total inorganic carbon
TOC	total organic carbon
TRU	transuranic

UFP	ultra-filtration process
VERSE-LC	VErsatile Reaction-SEparation model for Liquid Chromatography applications
WSRC	Westinghouse Savannah River Company
WTP	Hanford Tank Waste Treatment and Immobilization Plant
WTPSP	Waste Treatment Plant Support Project

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1.0 Introduction

The U.S. Department of Energy (DOE) Hanford Site contains more than 53 million gallons of legacy waste generated as a byproduct of plutonium production and reprocessing operations. The wastes are a complex mixture composed mostly of $NaNO_3$, $NaNO_2$, NaOH, $NaAlO_2$, Na_3PO_4, and Na_2SO_4, with a number of minor and trace metals, organics, and radionuclides stored in underground waste tanks. The DOE Office of River Protection (ORP) has contracted Bechtel National Incorporated (BNI) to build a pretreatment facility, the River Protection Project-Waste Treatment Plant (RPP-WTP), that will separate long-lived transuranics (TRU) and highly radioactive components (specifically ^{137}Cs and, in selected cases, ^{90}Sr) from the bulk (non-radioactive) constituents and immobilize the wastes by vitrification. The plant is designed to produce two waste streams: a high-volume low-activity waste (LAW) and a low-volume high-activity waste (HLW).

Ion exchange using the spherical resorcinol-formaldehyde (SRF) resin has been selected by WTP project and approved by DOE ORP for use in the Pretreatment Facility (PTF) of the RPP-WTP. The SRF resin is an engineered spherical form of the older ground gel resorcinol-formaldehyde (GGRF) resin, also termed resorcinol-formaldehyde (RF), which was developed and evaluated at the Westinghouse Savannah River Company (WSRC) in the 1980s (Ebra and Wallace 1983; Bibler et al. 1989). Numerous studies at Hanford and other DOE sites have shown the GGRF and SRF resins to be effective for removing ^{137}Cs from a wide variety of simulated and actual tank waste supernatants and for achieving less than the proposed spent waste classification criteria of <100 nCi TRU and <60 μCi ^{137}Cs per gram of spent resin (Adamson et al. 2006; Blanchard et al. 2008; Burgeson et al. 2004; Duignan and Nash 2009; Fiskum et al. 2006a; Fiskum et al. 2006b; Fiskum et al. 2006c; Fiskum et al. 2007; Hassan and Adu-Wusu 2003; King et al. 2004; Kurath et al. 1994; Nash et al. 2006).

Prior work has focused primarily on loading behavior for 5 M Na solutions at 25°C. Recent proposed changes to the process baseline indicate that both a broader range of sodium molarities (2 to 8 M) and higher temperatures may be required to alleviate post-filtration precipitation issues. Also, to date, no work has been done to establish the impact of organic compounds on the ion exchange system. The objective of this report is to summarize the results of the resin loading behavior under these various conditions.

Section 1.0 provides a brief historical background for HLW, Cs ion exchange, and the test design. Section 2.0 details the basis of the PNNL QA Program as applied to the RPP-WTP quality requirements. Section 3.0 describes the test design, solution and resin preparations, equipment, process steps, and chemical and radiochemical analyses. Section 4.0 provides a summary of the experimental data and includes a discussion of the results of the Cs ion exchange kinetics testing. Section 5.0 describes the modeling of the Cs ion exchange results, Section 6.0 provides a list of conclusions obtained from this experimental work, Section 7.0 provides a list of pertinent references, Appendix A lists experimental conditions, and Appendix B displays the analytical data.

2.0 Quality Assurance

The PNNL Quality Assurance (QA) Program is based on the requirements defined in the U.S. Department of Energy Order 414.1D, *Quality Assurance,* and 10 CFR 830, *Energy/Nuclear Safety Management*, and Subpart A—*Quality Assurance Requirements* (a.k.a. the Quality Rule). PNNL has chosen to implement the following consensus standards in a graded approach:

- ASME NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility Applications*, Part 1, Requirements for Quality Assurance Programs for Nuclear Facilities.
- ASME NQA-1-2000, Part II, Subpart 2.7, *Quality Assurance Requirements for Computer Software for Nuclear Facility Applications*.
- ASME NQA-1-2000, Part IV, Subpart 4.2, *Graded Approach Application of Quality Assurance Requirements for Research and Development*.

The procedures necessary to implement the requirements are documented through PNNL's "How Do I…?" (HDI [a]).

The Waste Treatment Plant Support Project (WTPSP) implements an NQA-1-2000 Quality Assurance Program, graded on the approach presented in NQA-1-2000, Part IV, Subpart 4.2. The WTPSP Quality Assurance Manual (QA-WTPSP-0002) describes the technology life cycle stages under the WTPSP Quality Assurance Plan (QA-WTPSP-0001). The technology life cycle includes the progression of technology development, commercialization, and retirement in process phases of basic and applied research and development (R&D), engineering and production and operation until process completion. The life cycle is characterized by flexible and informal quality assurance activities in basic research, which becomes more structured and formalized through the applied R&D stages.

The work described in this report has been completed under the QA technology level of Applied Research. WTPSP addresses internal verification and validation activities by conducting an Independent Technical Review of the final data report in accordance with WTPSP's procedure QA-WTPSP-601, Document Preparation and Change. This review verifies that the reported results are traceable, that inferences and conclusions are soundly based, and that the reported work satisfies the test plan objectives.

Section 5.0 is for information only. The work described in this section uses a commercially available software program (VERSE-LC) in order to model the kinetic experiments. However, the software was not added to the approved software list under the QA program and thus, despite the technical validity of the work presented in this section, must be considered for information only.

(a) System for managing the delivery of PNNL policies, requirements, and procedures.

3.0 Experimental

This section summarizes the SRF resin, resin preparation, simple simulant preparation, ion exchange system, and solution processing. Detailed laboratory test instructions were provided by internal documentation.[a,b,c,d,e] Data and observations were recorded on photocopied datasheets and the printed test instruction. Experimental conditions and analytical data are provided in Appendix A and Appendix B, respectively.

3.1 Loading Solution Preparation

The small-column loading kinetics testing task was performed using several non-radioactive aqueous solutions for loading the SRF resin. These loading simulant compositions (Table 3.1) were provided by BNI as documented in Test Specification, *RF Resin Cesium Removal with Expanded Load and Elution Conditions* (Lehrman 2010). The Na, Cs, Al, and OH concentrations were within the ranges expected for aqueous waste feeds to the PTF. The nominal Na concentration was selected to be between 2 M and 8 M, and the nominal Cs concentration was selected to be between 1.4E-05 M and 5.8E-05 M. No K was included in the simulant. The nominal free OH concentration was selected to be between 0.47 M and 4 M, and the Al concentration was selected to be between 0.0325 M and 0.334 M, approximately 90% of the solubility limit. The NaCl was only used to obtain the correct level of Na in the feed without adding more nitrate. The Cl level exceeded the contract amount. An evaluation of the impact of the higher concentration on kinetics was not conducted. These simple, loading simulants were not selected to represent any particular Hanford tank waste type.

Approximately 1 liter of each simple, loading simulant solution was prepared. All chemicals were added to the bottle based on weight (±0.1 g) and were within 0.1% of the target. The density of the loading simulants ranged from 1.086 g/mL to 1.371 g/mL using a 10-mL pycnometer. A new 1-liter batch of simulant was prepared as needed.

(a) RL Russell. 2010. *Simulant Preparation for Ion Exchange Kinetics Testing.* TI-WTPSP-024, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.
(b) RL Russell. 2010. *Small Column SRF Ion Exchange Kinetics Testing.* TI-WTPSP-026, Rev 0, Pacific Northwest National Laboratory, Richland, Washington.
(c) RL Russell. 2011. *Small Column SRF Ion Exchange Kinetics Testing Set 2.* TI-WTPSP-029, Rev 0, Pacific Northwest National Laboratory, Richland, Washington.
(d) RL Russell. 2011. *Batch Contact Elution Temperature Effect on Resin Tests.* TI-WTPSP-030, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.
(e) RL Russell. 2011. *Small Column SRF Ion Exchange Organic Impact Testing.* TI-WTPSP-042, Rev 0, Pacific Northwest National Laboratory, Richland, Washington.

Table 3.1. Planned Stock Simulant Solutions for Cesium Ion Exchange Loading

Stock ID No.[a]	2A05	2A10	5B17	8C20	8D40	8E40
Species (g/L)						
NaOH (s)	23.8969	48.0705	80.4969	96.5788	200.0953	200.0953
$Al(NO_3)_3$•$9H_2O$ (s)	12.1878	25.2406	43.2541	51.8502	125.3902	125.3902
$NaNO_3$ (s)	48.3798	39.5075	112.2604	474.7472	254.7639	254.7620
NaCl (s)	48.7014	19.4809	97.4026	0.0000	0.0000	0.0000
$CsNO_3$ (s)	0.0027	0.0027	0.0047	0.0057	0.0074	0.0113
Species (M)						
NaOH (s)	0.5975	1.2018	2.0126	2.4146	5.0027	5.0027
$Al(NO_3)_3$•$9H_2O$ (s)	0.0325	0.0673	0.1153	0.1382	0.3342	0.3342
$NaNO_3$ (s)	0.5692	0.4648	1.3207	5.5854	2.9973	2.9973
NaCl (s)	0.8333	0.3333	1.6667	0.0000	0.0000	0.0000
$CsNO_3$ (s)	1.4E-05	1.4E-05	2.4E-05	2.9E-05	3.8E-05	5.8E-05
Composition (M)						
Na[b]	2.0000	2.0000	5.0000	8.0000	8.0000	8.0000
Al[c]	0.0325	0.0673	0.1153	0.1382	0.3342	0.3342
Cs	1.4E-05	1.4E-05	2.4E-05	2.9E-05	3.8E-05	5.8E-05
OH-Total[d]	0.5975	1.2018	2.0126	2.4146	5.0027	5.0027
OH-Free[d]	0.4675	0.9327	1.5514	1.8618	3.6658	3.6658
NO_3	0.6667	0.6667	1.6667	6.0001	4.0001	4.0001
Cl[e]	0.8333	0.3333	1.6667	0.0000	0.0000	0.0000
Ratios (mol/mol)						
Initial Na/Cs	1.43E+05	1.43E+05	2.08E+05	2.76E+05	2.11E+05	1.38E+05
Na/Al	61.5603	29.7253	43.3651	57.8811	23.9344	23.9344
Na/NO_3	3.0000	3.0000	3.0000	1.3333	2.0000	2.0000
Na/OH_{Total}	3.3475	1.6641	2.4844	3.3131	1.5991	1.5991
Na/OH_{Free}	4.2780	2.1443	3.2230	4.2970	2.1824	2.1824
Density (g/mL)	1.086	1.087	1.211	1.371	1.344	1.348

(a) 1st Position: Initial Na M (**2**=2.00, **5**=5.00, **8**=8.00 M Na)
2nd Position: Initial Cs M (**A**=1.4E-05, **B**=2.4E-05, **C**=2.9E-05, **D**=3.8E-05, **E**=5.8E-05)
3rd Position: NaOH M Before Gibbsite (**05**=0.50, **10**=1.00, **17**=1.67, **20**=2.00, **40**=4.00).
(b) Sodium varied as per experimental design $[Na]_{Total}$ = 2, 5, or 8 M.
(c) Aluminum varied at 90% solubility as calculated from hydroxide per Li et al. (2005).
(d) Hydroxide varied per experimental design $[OH]_{Free}$ = 0.50, 1.00, 1.67, 2.00, 4.00 M.
(e) Chloride varied depending on $NaNO_3$ added to keep sodium at prescribed level.

3.2 Elution Solution Preparation

Elution (0.25 M HNO_3) and acid conversion solutions (0.50 M HNO_3) were prepared by volumetric dilution of reagent-grade concentrated HNO_3 with de-ionized (DI) water in a volumetric flask.

3.3 NaOH Solution Preparation

NaOH solutions for SRF resin pretreatment (1.0 M), regeneration (0.50 M), and feed displacement (0.10 M) were prepared by weighing (±0.1 g) 50% NaOH solution into volumetric flasks and diluting to volume using DI water.

3.4 Spherical RF Resin

The SRF resin used in these tests was from existing stock (Microbeads, Skedsmokorset, Norway, Lot Number 5E-370/641) that had been stored at PNNL for more than 4 years. The resin had been stored in the H^+-form in water under N_2 in sealed 2-L plastic bottles. A small (~3 mm) layer of the resin was dark brown, indicating possible oxidative degradation, in contrast to the orange color of the remaining bulk. Upon opening the container, the top layer of resin was removed by vacuum sluicing and disposed of without use. The remaining resin was thoroughly mixed, and a representative sample was removed for use in the experiment using a coring technique consistent with the American Society for Testing and Materials (ASTM) Method 2687, Standard Practice for Sampling Particulate Ion-Exchange Materials (ASTM 2001). Even after vacuum sluicing of the top, darker brown layer and mixing the remaining material, a small fraction (<1%) of the sampled resin still exhibited the darker brown color as shown in Figure 3.1. The small fraction was deemed inconsequential and no further separation was attempted. Figure 3.2 displays an example visible light microscopy image of the SRF resin.

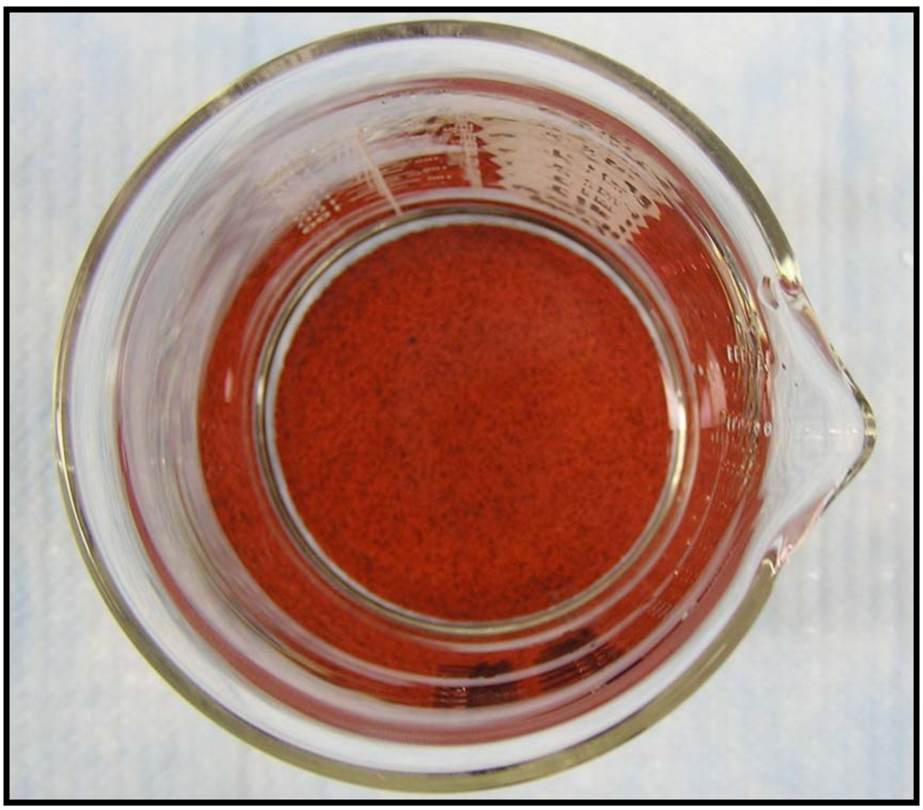


Figure 3.1. Representative SRF Resin Sample for Column Testing Showing Darkened Resin Beads

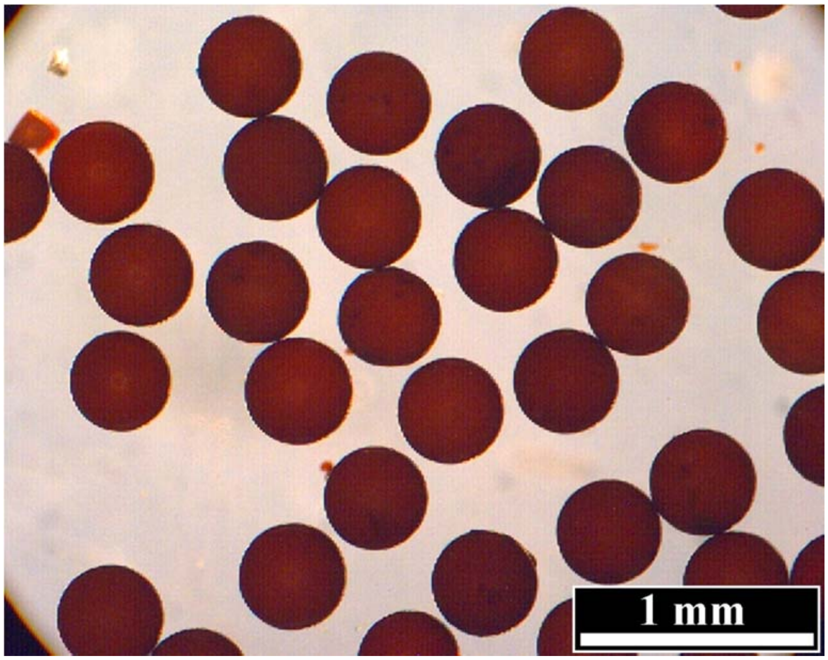


Figure 3.2. Spherical Resorcinol-Formaldehyde Resin

3.5 Resin Pretreatment Processing

Approximately 10.7 mL of the resin (H^+-form) was dispensed into five 25-mL graduated cylinders and allowed to settle for more than 30 minutes to a constant volume during tapping/vibration. The resin sub-samples were then transferred into 100-mL glass beakers. One was used for the kinetics loading column experiments. The remaining four sub-samples, two in the H^+-form and two that had been converted to the Na^+-form, were dried to a constant mass at 50°C in a vacuum oven. Constant mass was defined as <0.1% mass variation over two consecutive measurements taken at an interval of at least 7 h. The average density was calculated to be 0.456 g/mL (mass of dried H^+-form resin per mL of settled H^+-form resin under water in a 25-mL graduated cylinder) and is consistent with values reported previously (Fiskum et al. 2006b; Fiskum et al. 2006c).

Figure 3.3 displays a comparison of the H^+- and Na^+-forms of the SRF resin. The left-most cylinder contains the orange-colored, H^+-form of the resin (~10.7 mL), while the three right-most cylinders contain the final, dark black/brown-colored, pretreated Na^+-form of the resin (~15.7 mL). The volume of the initial H^+-form resin aliquot expanded slightly more than the targeted 15-mL volume that was based on previous reports (Fiskum et al. 2006a; Fiskum et al. 2006b).

The overall resin bulk pretreatment and column pretreatment steps are shown in Table 3.2 and are consistent with previous testing[a] (Arm and Blanchard 2004; Fiskum et al. 2006b; Fiskum et al. 2006c). The bulk pretreatment processes utilized a full resin expansion/contraction cycle in an open beaker format, which allows for full expansion of the resin without being constrained inside the ion exchange column (Fiskum et al. 2007).

(a) CA Nash and CE Duffey. August 17, 2004. *Hanford RPP-WTP Alternate Resin Program -Protocol P1-RF: Spherical Resin Sampling from Containers, Resin Pretreatment, F-Factor, and Resin Loading to Column*, WTP 097893, Savannah River National Laboratory.

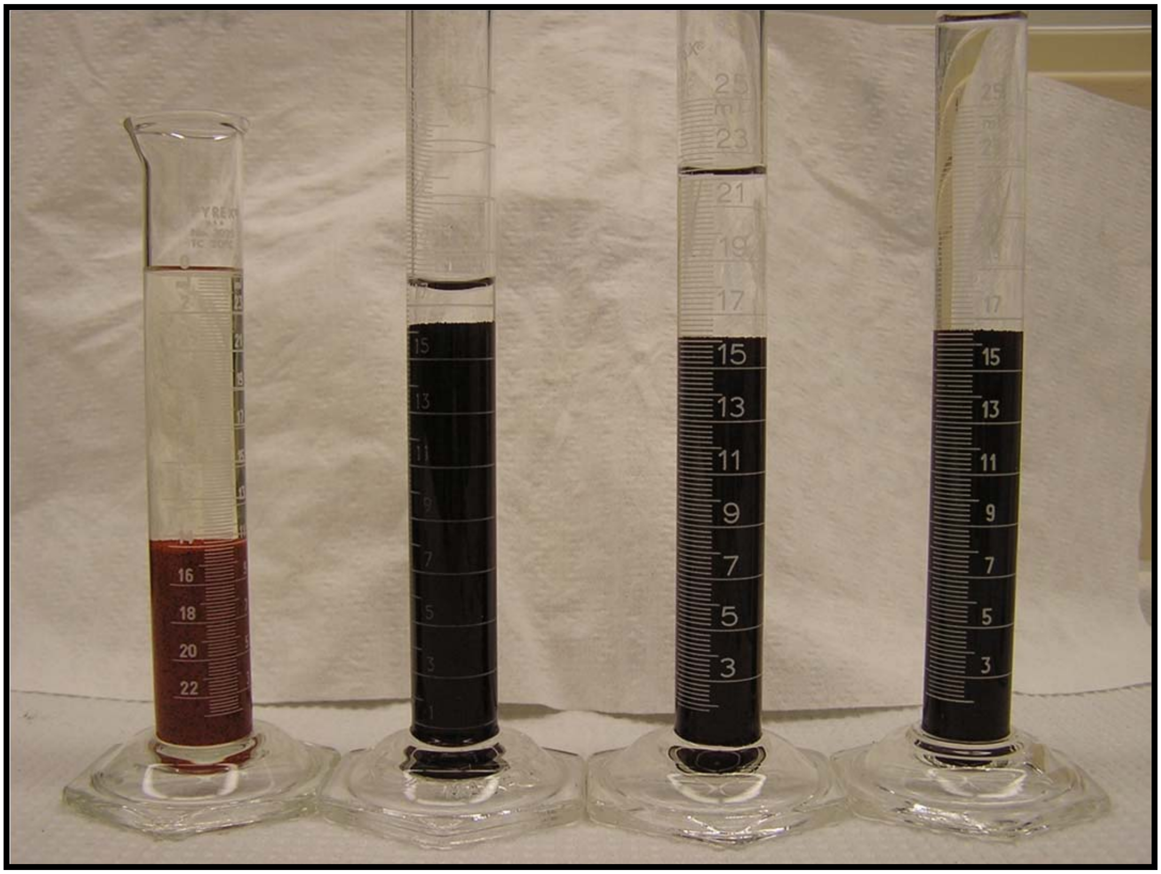


Figure 3.3. SRF Resin Dispensed for Column Experiments. Left column in H^+-form and others in Na^+-form.

Following bulk pretreatment, the Na^+-form resin was slurry-transferred into the ion exchange column, rinsed with DI water, and converted into the H^+-form with up-flow 0.5 M HNO_3. The resin was then re-converted back into the Na^+-form with up-flow 0.5 M NaOH.

Table 3.2. Ion Exchange Pretreatment and Process Steps

Process/Pretreatment Step	Solution	Volume	Time	Mixing	Flowrate
Bulk Pretreatment					
Water Rinse	DI Water	5 RV[(a)]	30 min	Swirl[(b)]	NA[(c)]
Resin Expansion	1 M NaOH	5 RV	1 h	Swirl	NA
Resin Expansion	1 M NaOH	5 RV	>12 h	Soak	NA
Water Rinse – 1st	DI Water	3RV	30 min	Swirl	NA
Water Rinse – 2nd	DI Water	3RV	30 min	Swirl	NA
Water Rinse – 3rd	DI Water	3RV	30 min	Swirl	NA
Resin Conversion	0.5 M HNO_3	10 RV	2 h	Swirl	NA
Water Rinse – 4th	DI Water	3 RV	1 min	Swirl	NA
Resin Expansion	1 M NaOH	10 RV	1 h	Swirl	NA
Water Rinse – 5th	DI Water	10 RV	1 min	Swirl	NA

Table 3.2. Ion Exchange Pretreatment and Process Steps (contd)

Process/Pretreatment Step	Solution	Volume	Time	Mixing	Flowrate
Column Pretreatment					
Water Rinse	DI Water	7.5 BV[(d)]	2.5 h	Flow	3 BV/h
Acid Rinse	0.5 M HNO_3	8 BV	2.7 h	Flow	3 BV/h
Water Rinse	DI Water	3 BV	1 h	Flow	3 BV/h
Feed Prep	0.5 M NaOH	6 BV	2 h	Flow	3 BV/h
Column Loading/Elute					
Simulant	Simulant	variable	10 h	Flow	variable
Feed Displaced	0.1 M NaOH	7.5 BV	2.5 h	Flow	3 BV/h
Water Rinse	DI Water	7.5 BV	2.5 h	Flow	3 BV/h
Neutralization	0.5 M HNO_3	3 BV	1 h	Flow	3 BV/h
Acid Elution	Variable	28 BV	10 h	Flow	2.8 BV/h
Water Rinse	DI Water	3 BV	1 h	Flow	3 BV/h
Regeneration	0.5 M NaOH	6 BV	2 h	Flow	3 BV/h

(a) Resin volume (RV).
(b) Gently swirling by hand every 10 min.
(c) Not applicable (NA).
(d) Bed volume (BV).

3.6 Ion Exchange Column System

The kinetics experimental setup was based on a differential column concept described in detail previously (Duffey et al. 2003). This concept uses a thin resin bed exposed to a feed solution with nearly uniform uptake throughout the bed. In essence, this setup is designed to determine resin adsorption properties of a differential cross-sectional area of an ion exchange column. Implementation requires a controlled flow of liquid through the resin bed, a controlled temperature throughout the system, and continuous homogenization of the liquid phase. A schematic of the kinetics experimental setup is shown in Figure 3.4 with an actual picture of the system shown in Figure 3.5.

Resin test samples were placed into the jacketed column. The resin was held in place between 200 mesh stainless steel screens. The simulant was fed through the column in an up-flow manner to minimize the amount of air initially in the system. The entire system remained closed with the exception of a small vent/sampling port. The target resin bed path length and diameter were 10.1 mm and 15.0 mm respectively, giving a target resin volume of 1.8 mL, which is similar to those reported by Duffey et al. (2003).

The simulant feed was held within a capped 125-mL polyethylene bottle and was continually stirred with a 1-inch PTFE stir bar. Approximately 2-mL samples were taken from the bottle at 0, 6, 12, 18, 24, 36, 48, 60, 80, 120, 180, 240, and 600 minutes using a 10-mL plastic syringe with a 4-inch #18 stainless steel needle. The feed bottle was wrapped in a heat jacket that was temperature controlled using a thermocouple and temperature controller. These experiments were conducted with a Stepdos reduced pulsation diaphragm-metering pump (KNF Neuberger, Trenton, NJ) with a PVDF (polyvinylidene fluoride) head, FFPM (perfluorinated elastomer) valves and gaskets, and PTFE (polytetrafluoroethylene)-coated diaphragm. The jacketed column temperature was controlled using a Haake DC-5 (Thermo Electron, Newington, NH) recirculating chiller/heater.

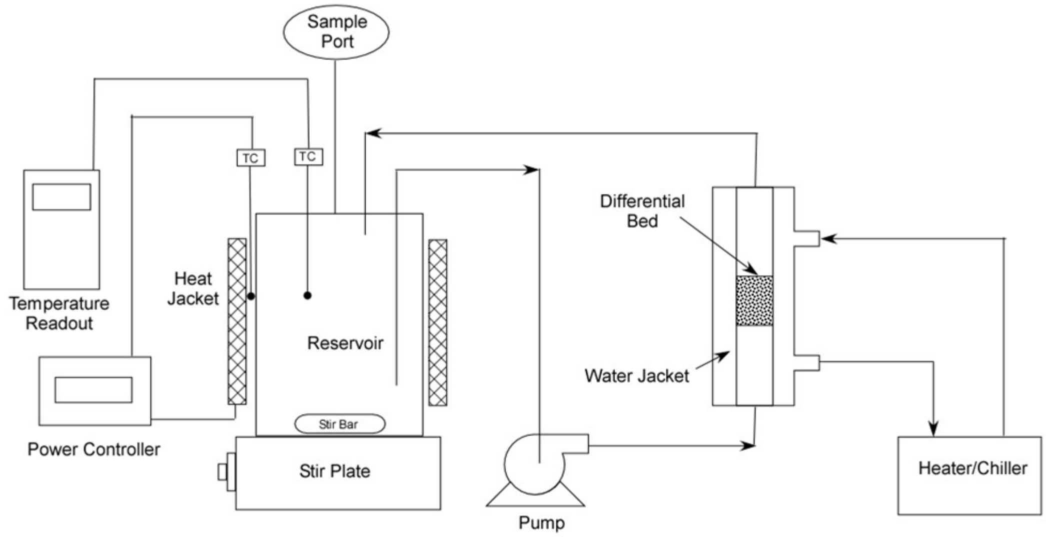


Figure 3.4. Differential Column Ion Exchange Kinetics Schematic

Figure 3.5. Ion Exchange Kinetics Testing Apparatus

3.7 Column Testing Experimental Procedure

A series of column loading and elution cycles was completed as detailed in Table 3.3. The composition of the simulants used is shown in Table 3.1. The general column processing steps (e.g., pretreatment, loading, feed displacement, rinsing, elution, rinsing, and regeneration) are described in Table 3.3.

Table 3.3. Cesium Loading Kinetics Experimental Design

	Ion Exchange Kinetic Loading Conditions							Column Elution Conditions				
Run ID[a]	h [b,c]	T °C	Cs[d] C/C_0	Flow Velocity cm/min	Na M	OH M	Initial Cs, M	T °C	BV [e]	BV/h[f]	HNO_3 M[e]	Cs M
Test-1-A-1	10	45	0.52	6	5.0	1.67	2.4E-05	25	25	2.8	0.25	0
Test-1-A-2	10	45	0.52	6	8.0	2.0	2.9E-05	25	25	2.8	0.25	0
Test-1-A-3	10	45	0.52	4	8.0	2.0	2.9E-05	25	25	2.8	0.25	0
Test-1-A-4	10	45	0.52	6	8.0	4.0	5.8E-05	25	NA	NA	NA	0
Test-1-A-4B	720	45	0.52	<0.1[g]	8.0	4.0	5.8E-05	25	25	2.8	0.25	0
Test-1-A-5	10	45	0.52	6	5.0	1.67	2.4E-05	25	25	2.8	0.25	0
Test-1-B-1	10	50	0.52	6	5.0	1.67	2.4E-05	25	25	2.8	0.25	0
Test-1-B-2	10	50	0.52	8	2.0	0.50	1.4E-05	25	25	2.8	0.25	0
Test-1-B-3	10	50	0.52	4	2.0	0.50	1.4E-05	25	25	2.8	0.25	0
Test-1-B-4	10	50	0.52	4	8.0	4.0	2.9E-05	25	NA	NA	NA	0
Test-1-B-4B	720	65	0.52	<0.1[g]	8.0	4.0	2.9E-05	25	25	2.8	0.25	0
Test-1-B-5	10	50	0.52	6	5.0	1.67	2.4E-05	25	25	2.8	0.25	0
Test-1-C-1	10	50	0.52	6	5.0	1.67	2.4E-05	25	25	2.8	0.25	0
Test-1-C-2	10	50	0.52	8	2.0	1.0	1.4E-05	25	25	2.8	0.25	0
Test-1-C-3	10	50	0.52	4	2.0	1.0	1.4E-05	25	25	2.8	0.25	0
Test-1-C-4	10	50	0.52	8	8.0	4.0	3.8E-05	25	NA	NA	NA	0
Test-1-C-4B	720	75	0.52	<0.1[g]	8.0	4.0	3.8E-05	25	25	2.8	0.25	0
Test-1-C-5	10	50	0.52	6	5.0	1.67	2.4E-05	25	25	2.8	0.25	0
Test-1-D-1	10	25	0.52	6	5.0	1.67	2.4E-05	25	25	2.8	0.25	0
Test-1-E-1	10	50	0.52	6	5.0	1.67	2.4E-05	25	25	2.8	0.25	0
Test-1-E-2	10	50	0.52	6	8.0	2.0	2.9E-05	25	25	2.8	0.25	0
Test-1-E-3	10	50	0.52	4	8.0	2.0	2.9E-05	25	25	2.8	0.25	0
Test-1-E-4	10	50	0.52	6	8.0	4.0	5.8E-05	25	NA	NA	NA	0
Test-1-E-4B	720	50	0.52	<0.1[g]	8.0	4.0	5.8E-05	25	25	2.8	0.25	0
Test-1-E-5	10	50	0.52	6	5.0	1.67	2.4E-05	25	25	2.8	0.25	0
Test-1-F-1	10	55	0.52	6	5.0	1.67	2.4E-05	25	25	2.8	0.25	0
Test-1-F-2	10	55	0.52	6	8.0	2.0	2.9E-05	25	25	2.8	0.25	0
Test-1-F-3	10	55	0.52	4	8.0	2.0	2.9E-05	25	25	2.8	0.25	0
Test-1-F-4	10	55	0.52	6	8.0	4.0	5.8E-05	25	NA	NA	NA	0
Test-1-F-4B	720	55	0.52	<0.1[g]	8.0	4.0	5.8E-05	25	25	2.8	0.25	0
Test-1-F-5	10	55	0.52	6	5.0	1.67	2.4E-05	25	25	2.8	0.25	0
Test-1-G-1	10	60	0.52	6	5.0	1.67	2.4E-05	25	25	2.8	0.25	0
Test-1-G-2	10	60	0.52	6	8.0	2.0	2.9E-05	25	25	2.8	0.25	0
Test-1-G-3	10	60	0.52	4	8.0	2.0	2.9E-05	25	25	2.8	0.25	0
Test-1-G-4	10	60	0.52	6	8.0	4.0	5.8E-05	25	NA	NA	NA	0
Test-1-G-4B	720	60	0.52	<0.1[g]	8.0	4.0	5.8E-05	25	25	2.8	0.25	0
Test-1-G-5	10	60	0.52	6	5.0	1.67	2.4E-05	25	25	2.8	0.25	0

(a) Each test series (e.g., A, B, C, D, E, F and G) represented an independent ion exchange column that was loaded and eluted one or more times using the conditions listed. The exact BV of the ion exchange resin depended on the final construction of the apparatus but was ~1 to 2 mL.

(b) Resin loading was expected to require approximately 10 h to achieve kinetic equilibrium. Samples were collected periodically to define the cesium uptake curve (e.g., 0, 6, 12, 18, 24, 36, 48, 60, 80, 120, 180, 240, 600 min).

(c) The 10-h kinetics tests were completed at temperatures specified for each run. Six extended-duration (720 h) solution flow tests were completed at 45°, 50°, 55°, 60°, 65° and 75°C. Most of the extended run tests were aborted after ~336 hours due to resin degradation and column plugging.

(d) The total simulant solution volume was varied to target an expected loading of 0.52 C/C_0 where C_o is the initial concentration.

(e) BV = Bed Volume. Elution with 0.25 M HNO_3 commenced after feed displacement (7.5 BV 0.1 M NaOH) and water rinse (7.5 BV DI Water) solutions were passed through the column. A single elution composite sample was collected and analyzed.

(f) The flow rate for elution was expected to be approximately 2.8 BV/h. The flow rate was approximately 5 mL/h and the equivalent BV/h varied slightly with the exact BV for each column.

(g) The actual flow velocity was limited by the pump configuration and was determined at the time of experimentation but was estimated to be approximately 0.08 cm/min.

The ion exchange columns were loaded with simulant feed solution at temperatures of 25, 45, 50, 55, 60, 65, and 75± 2°C. The solution was processed at various linear flow velocities (4, 6, and 8 cm/min) as shown in Table 3.3. Following loading, the feed solution was displaced with 7.5 BVs of 0.1 M NaOH, rinsed with 7.5 BVs of DI water, and the resin was neutralized with 3 BVs of 0.5 M HNO_3 at 3 BV/h as is outlined in Table 3.3.

The ion exchange columns were eluted with approximately 28 BVs of HNO_3 processed at 25°C and at 2.8 BV/h. As is shown in Table 3.3, the elution solution for each cycle was 0.25 M HNO_3. Following elution, the columns were rinsed with 3 BVs of DI water and regenerated with 6 BVs 0.5 M NaOH at 3 BV/h before beginning the next loading cycle. Weights of each sample and the temperature of the simulant were recorded for each sampling.

Simulant samples were submitted to Southwest Research Institute (SwRI) for analysis. Analysis methods included inductively coupled plasma-mass spectroscopy (ICP-MS) for Cs, inductively coupled plasma-optical emission spectroscopy (ICP-OES) for Na and Al, ion chromatography (IC) for anions and titration for OH analysis. Quality assurance and control procedures using blanks, duplicates, and spikes along with standard results for each analysis set are maintained in records and are not reported here.

3.8 Batch Experiments

Fresh SRF resin was contacted with 0.5 M HNO_3 while continually mixing on a shaker for 70 days at three different temperatures (~25°C, 45°C, and 55°C). A fourth set of samples of fresh resin were contacted with DI water at ~25°C as control samples while continually mixing on a shaker for 70 days. A ratio of 1:100 was used for all resin and solution mixtures (0.1 g resin in 10 mL solution). After 70 days, the resin was removed from the acid (or DI water), rinsed three times for 30 minutes each time with 10 mL of DI water and then contacted twice with 10 mL of 0.5M NaOH, once for an hour and then once for 24 hours, to convert the resin to the Na^+-form. After the 24-hour NaOH contact, all of the resin was removed and contacted with 25 mL of the Cs loading solution (5 M Na, 1.67 M OH, 0.12 M Al, 1.67 M Cl, 1.67 M NO_3 and 2.4E-05 M Cs). The experimental matrix is shown in Table 3.4. Analytical samples were collected at 0, 1, 4, 10, and 24 hours from individual batches of resin and loading solution to define the Cs uptake curve. Samples were filtered ~10 mL of supernate from the sample bottle using a 0.45 µm disposable syringe filter and placing it in the specified sample vial. Each test was performed in duplicate with a blank sample taken at 0 and 24 hours for the 25°C and 45°C tests. Simulant samples were submitted to SwRI for analysis. Analysis methods included ICP-MS for Cs, ICP-OES for Na and Al, IC for anions and titration for OH analysis. Quality assurance and control procedures using blanks, duplicates, and spikes along with standard results for each analysis set are maintained in records and are not reported here.

Table 3.4. Batch Contact Elution Temperature Experimental Design

Run ID	h	T °C	HNO_3 Aged?	Na M	OH M	Initial Cs, M
Test-25-A-0	0	25	Y	5.0	1.67	2.4E-05
Test-25-A-1	1	25	Y	5.0	1.67	2.4E-05
Test-25-A-4	4	25	Y	5.0	1.67	2.4E-05
Test-25-A-10	10	25	Y	5.0	1.67	2.4E-05
Test-25-A-24	24	25	Y	5.0	1.67	2.4E-05
Test-25-B-0	0	25	Y	5.0	1.67	2.4E-05
Test-25-B-1	1	25	Y	5.0	1.67	2.4E-05
Test-25-B-4	4	25	Y	5.0	1.67	2.4E-05
Test-25-B-10	10	25	Y	5.0	1.67	2.4E-05
Test-25-B-24	24	25	Y	5.0	1.67	2.4E-05
Test-25-C-0	0	25	N	5.0	1.67	2.4E-05
Test-25-C-1	1	25	N	5.0	1.67	2.4E-05
Test-25-C-4	4	25	N	5.0	1.67	2.4E-05
Test-25-C-10	10	25	N	5.0	1.67	2.4E-05
Test-25-C-24	24	25	N	5.0	1.67	2.4E-05
Test-25-D-0	0	25	N	5.0	1.67	2.4E-05
Test-25-D-1	1	25	N	5.0	1.67	2.4E-05
Test-25-D-4	4	25	N	5.0	1.67	2.4E-05
Test-25-D-10	10	25	N	5.0	1.67	2.4E-05
Test-25-D-24	24	25	N	5.0	1.67	2.4E-05
Test-45-A-0	0	45	Y	5.0	1.67	2.4E-05
Test-45-A-1	1	45	Y	5.0	1.67	2.4E-05
Test-45-A-4	4	45	Y	5.0	1.67	2.4E-05
Test-45-A-10	10	45	Y	5.0	1.67	2.4E-05
Test-45-A-24	24	45	Y	5.0	1.67	2.4E-05
Test-45-B-0	0	45	Y	5.0	1.67	2.4E-05
Test-45-B-1	1	45	Y	5.0	1.67	2.4E-05
Test-45-B-4	4	45	Y	5.0	1.67	2.4E-05
Test-45-B-10	10	45	Y	5.0	1.67	2.4E-05
Test-45-B-24	24	45	Y	5.0	1.67	2.4E-05
Test-45-BB-0	0	45	N	5.0	1.67	2.4E-05
Test-45-BB-24	24	45	N	5.0	1.67	2.4E-05
Test-55-A-0	0	55	Y	5.0	1.67	2.4E-05
Test-55-A-1	1	55	Y	5.0	1.67	2.4E-05
Test-55-A-4	4	55	Y	5.0	1.67	2.4E-05
Test-55-A-10	10	55	Y	5.0	1.67	2.4E-05
Test-55-A-24	24	55	Y	5.0	1.67	2.4E-05
Test-55-B-0	0	55	Y	5.0	1.67	2.4E-05
Test-55-B-1	1	55	Y	5.0	1.67	2.4E-05
Test-55-B-4	4	55	Y	5.0	1.67	2.4E-05
Test-55-B-10	10	55	Y	5.0	1.67	2.4E-05
Test-55-B-24	24	55	Y	5.0	1.67	2.4E-05

3.9 Organic Column Test

The impact of organics test was performed using the simulant ID 5B17 listed in Table 3.1 with the organics listed in Table 3.5 and Table 3.6 added. The organics were added at a ratio of 0.54 mol TOC per mol Na, which compares closely to the BNI contract specification of 0.5 mol TOC per mol of Na. The simulant solution was prepared in the same manner as described in Section 3.1 with the organics added at the end to make 250 mL. The antifoam agent (Dow Corning Q2-3183A antifoam) was added at a concentration of 2000 ppm and the antifoam degradation products were added at 1000 ppm. After adding the antifoam and antifoam degradation products, the solution had a significant amount of gelatinous material present. Therefore, it was filtered through a KimWipe™ paper to remove this before filtering through a 0.1 µm filter. A total inorganic carbon and total organic carbon (TIC/TOC) analysis of the feed was performed both before filtering and after filtering had occurred. Some of this gelatinous material adhered to the flask as shown in Figure 3.6.

Table 3.5. Antifoam Degradation Products Added to Organic Feed Solution

Chemical	Formula	CAS#	Sp.G	Molecular Weight
Dimethyl-oxo-silane (or dimethylsilanediol, DMSD)	$(C_2H_6OSi)_n$ (n = 1)	9087-49-4		74.154
Hexamethylcyclotrisiloxane (D_3)	$C_6H_{18}O_3Si_3$ or $(C_2H_6OSi)_3$	541-05-9	1.02	222.46
Octamethylcyclotetrasiloxane (D_4)	$C_8H_{24}O_4Si_4$ or $(C_2H_6OSi)_4$	556-67-2	0.95	296.62
Decamethylcyclopentasiloxane (or Cyclomethicone, D_5)	$C_{10}H_{30}O_5Si_5$ or $(C_2H_6OSi)_5$	541-02-6	0.96	370.78
Dodecamethylcyclohexansiloxane (or Cyclohexasiloxane, D_6)	$C_{12}H_{36}O_6Si_6$ or $(C_2H_6OSi)_6$	540-97-6	0.96	444.93

Table 3.6. Organic Products Added to Organic Feed Solution

Chemical	Formula	CAS#	Spike Level (mg/L)
Benzene	C_6H_6	71-43-2	18.7
Chloroform	$CHCl_3$	67-66-3	18.7
1,2-Dichloroethane	$C_2H_4Cl_2$	107-06-2	18.7
1,1-Dichloroethylene	$C_2H_2Cl_2$	75-35-4	18.7
Hexachlorobutadiene	C_4Cl_6	87-68-3	18.7
Hexachloroethane	C_2Cl_6	67-72-1	84.8
Methylethylketone	C_4H_8O	78-93-3	18.7
Nitrobenzene	$C_6H_5NO_2$	98-95-3	84.8
Pyridine	C_5H_5N	110-86-1	84.8
Tetrachloroethylene	C_2Cl_4	127-18-4	18.7
Trichloroethylene	C_2HCl_3	79-01-6	18.7
Acetone	CH_3COCH_3	67-64-1	101.8
n-Butyl alcohol	$C_4H_{10}O$	71-36-3	18.7
Carbon disulfide	CS_2	75-15-0	18.7
O-Dichlorobenzene	$C_6H_4Cl_2$	95-50-1	18.7
Ethyl acetate	$CH_3COOC_2H_5$	141-78-6	84.8
Ethyl benzene	C_8H_{10}	100-41-4	18.7
Isobutyl alcohol	$(CH_3)_2CHCH_2OH$	78-83-1	84.8
Methanol	CH_4O	67-56-1	18.7
Methylene chloride	CH_2Cl_2	75-09-2	18.7
Methyl isobutyl ketone	$C_6H_{12}O$	108-10-1	18.7
Toluene	$C_6H_5CH_3$	108-88-3	18.7
1,1,1-Trichloroethane	$C_2H_3Cl_3$	71-55-6	18.7
1,1,2-Trichloroethane	$C_2H_3Cl_3$	79-00-5	18.7
Trichloromonofluoromethane	CCl_3F	75-69-4	18.7
Xylene-mixed isomers	C_8H_{10}	1330-20-7	18.7

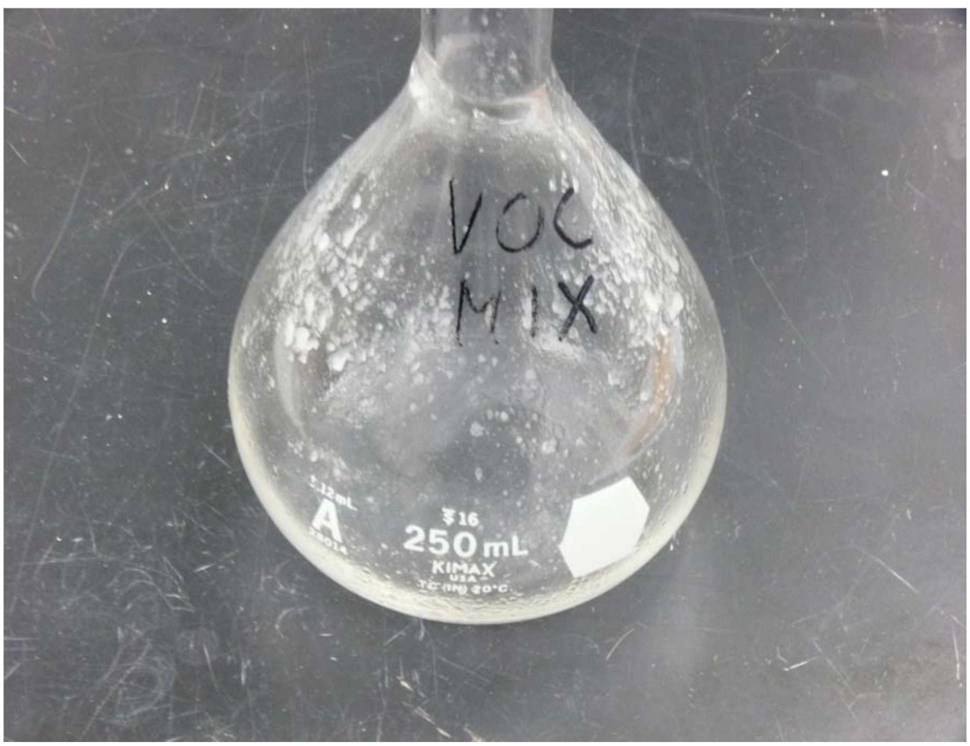


Figure 3.6. Volumetric Flask After Mixing Organic Feed Solution

The ion exchange column was loaded with simulant feed solution at a temperature of 45±2°C. The solution was processed at a linear flow velocity of 6 cm/min for the 10 h of loading. These conditions were identical to Test 1-A-1 in Table 3.3. Following loading, the feed solution was displaced with 7.5 BVs of 0.1 M NaOH, rinsed with 7.5 BVs of DI water, and the resin was neutralized with 3 BVs of 0.5 M HNO_3 at 3 BV/h as is outlined in Table 3.3.

The ion exchange column was then eluted with approximately 28 BVs of 0.25 M HNO_3 processed at 25°C and at 2.8 BV/h. Following elution, the column was rinsed with 3 BVs of DI water. Weights of each sample and the temperature of the simulant were recorded at each sampling.

Simulant samples were submitted to SwRI for analysis. Analysis methods included ICP-MS for Cs, ICP-OES for Na and Al, IC for anions, titration for OH analysis, total inorganic carbon (TIC), and total organic carbon (TOC). Quality assurance and control procedures using blanks, duplicates, and spikes along with standard results for each analysis set are maintained in records and are not reported here.

4.0 Results and Discussion

This research examined the impact of linear load velocity (4, 6, 8 cm/min), initial Na concentration (2, 5, 8 M), initial Na/Cs ratio (1.4E+05, 2.1E+05, 2.8E+05 mol/mol), initial Na/OH ratio (2.0, 3.0, 4.0 mol/mol), and high free OH concentration (4 M) on resin loading kinetics and resin degradation during extended solution flow using elevated temperatures (45°, 50°, 55°, 60°, 65°, 75°C). The results of this research are discussed in this section. In addition, the effect of aging the resin in an acid environment and the effect on the resin of volatile organics in the feed were also tested and are discussed here as well.

4.1 Impacts of Variables on Loading Kinetics

A series of column loading and elution cycles were completed using a fractional factorial experimental design as detailed in Table 3.3. This allowed each variable to be studied as well as the variable interactions. The axial velocity, sodium concentration, hydroxide concentration, cesium-to-sodium ratio, and cesium concentration were the primary variables studied. Tests were then compared using ones that had similar variables except for the one being analyzed.

The results from these tests were used to assess the impact of process conditions on the diffusivity and film mass transfer coefficient. Tests performed at varying axial velocity provided a measure of the impact of the film mass transfer coefficient. Tests performed at varying sodium concentrations and cesium-to-sodium ratios provided a measure of the impact of the diffusivity on ion exchange performance.

It was found that linear load velocity had a significant impact on the loading kinetics of the column as shown in Figure 4.1. The higher the loading velocity, the faster the column loaded. This is shown by comparing Test E2 to E3 and Test C2 to C3. The other pairs with the same variables tested showed the same trends. This indicates that the loading rate of the WTP ion exchange columns may be controlled by the rate the feed is passed through the column. However, the highest linear load velocity tested corresponds to the design feed rate of 30 gpm and it hasn’t been tested to show that this correlation is true at higher linear load rates or if there is a limiting maximum.

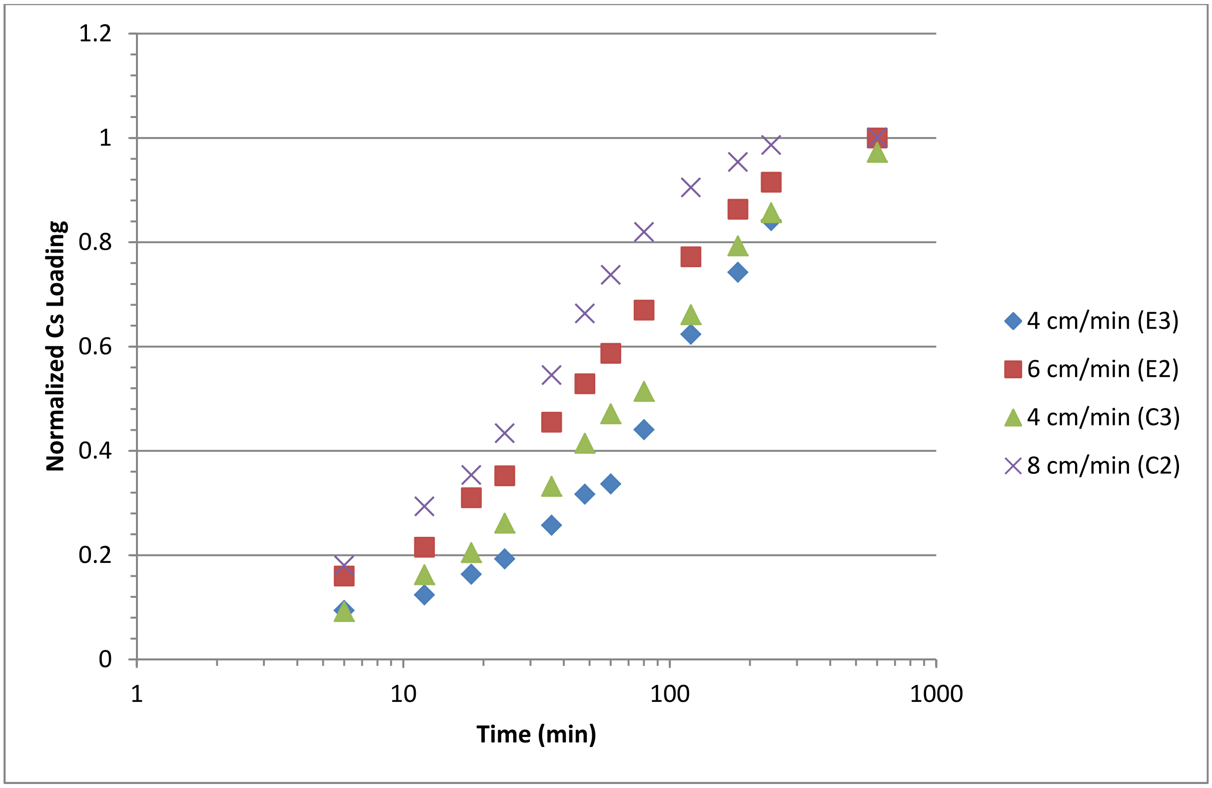


Figure 4.1. Velocity Impact on Kinetics of Column Loading

The levels of initial Na concentration tested made little difference in the loading kinetics of the column as shown in Figure 4.2. The loading curves for both 5 M Na and 8 M Na lie almost on top of each other. The loading curve for 2 M Na may have a slight effect on the loading kinetics but was insignificant compared to the effect of the linear velocity and was not worth pursuing. The only tests performed using 2 M Na had several different variables which would affect the data and it wouldn't be a clean comparison.

Also, neither the initial Na/Cs ratio nor the Na/OH ratio affected the loading kinetics as shown in Figure 4.3 and Figure 4.4. Regardless of the initial ratio, the column loaded at essentially the same rate as demonstrated by nearly overlapping Cs uptake curves. This indicates that the WTP should not have a problem processing high Na content (up to 8 M Na) feeds through the ion exchange column. However, there will be a difference in that at higher Na levels, the overall Cs uptake will be lower as shown in Figure 4.5. These tests showed between a 10% and 15% decrease in Cs uptake when the Na was increased from 5 M to 8 M Na.

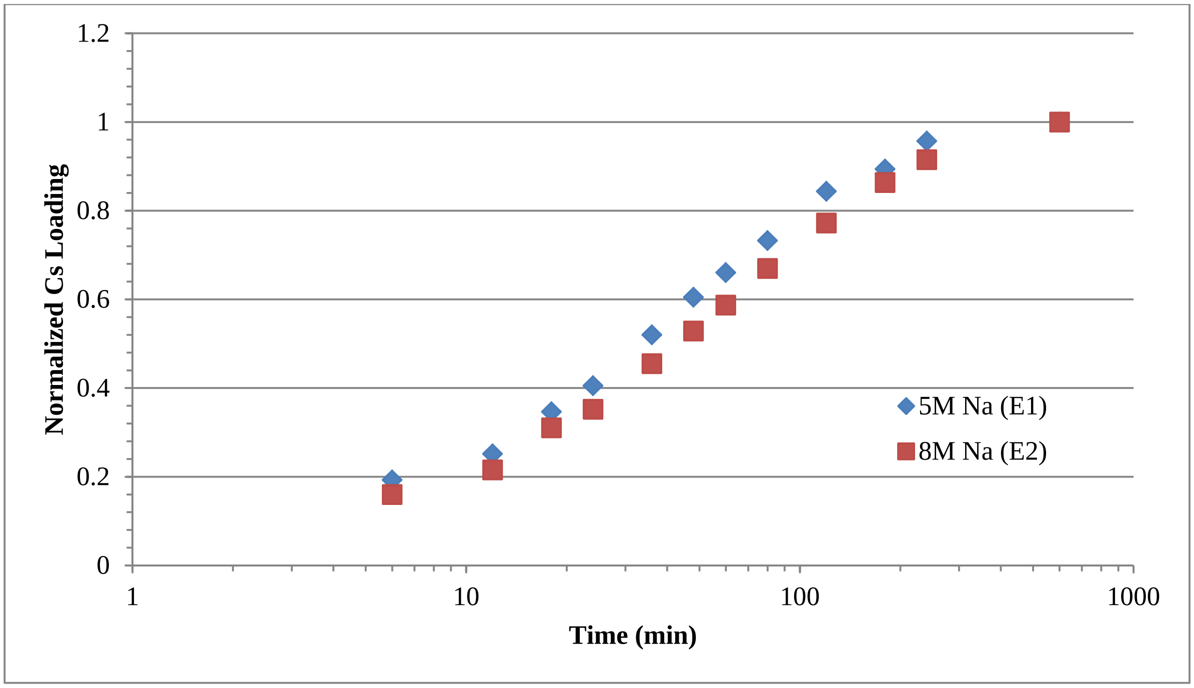


Figure 4.2. Initial Na Impact on Kinetics of Column Loading

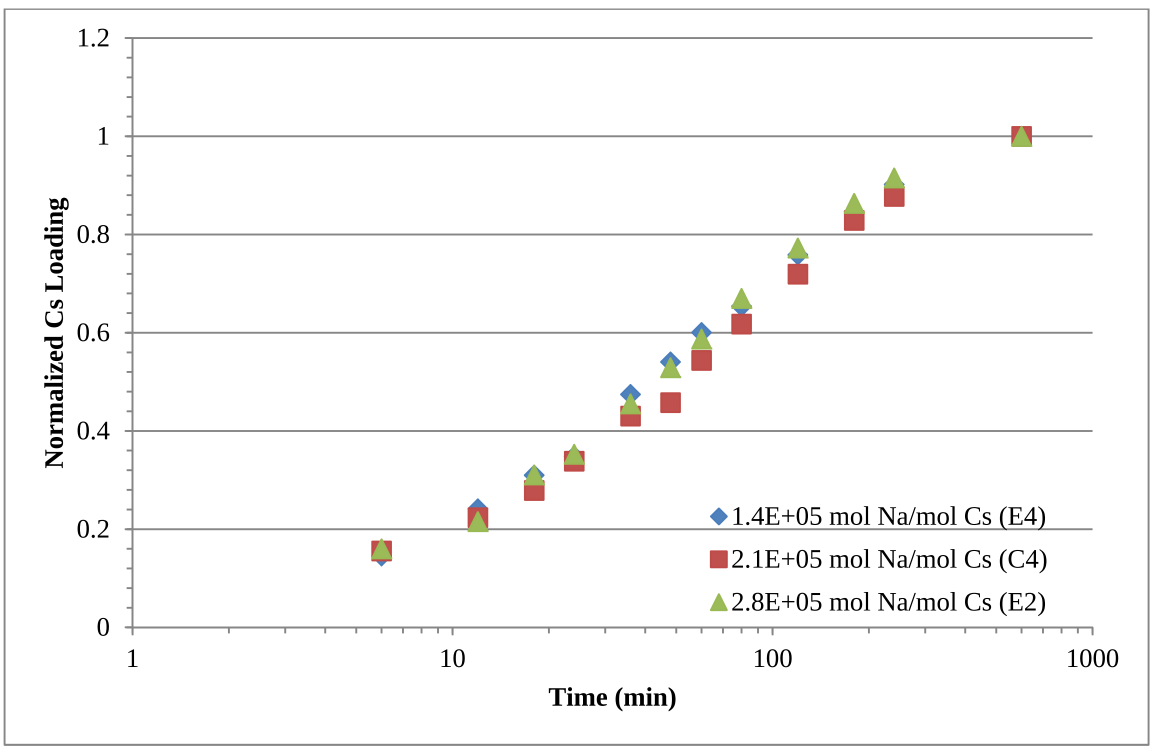


Figure 4.3. Na/Cs Ratio Impact on Kinetics of Column Loading

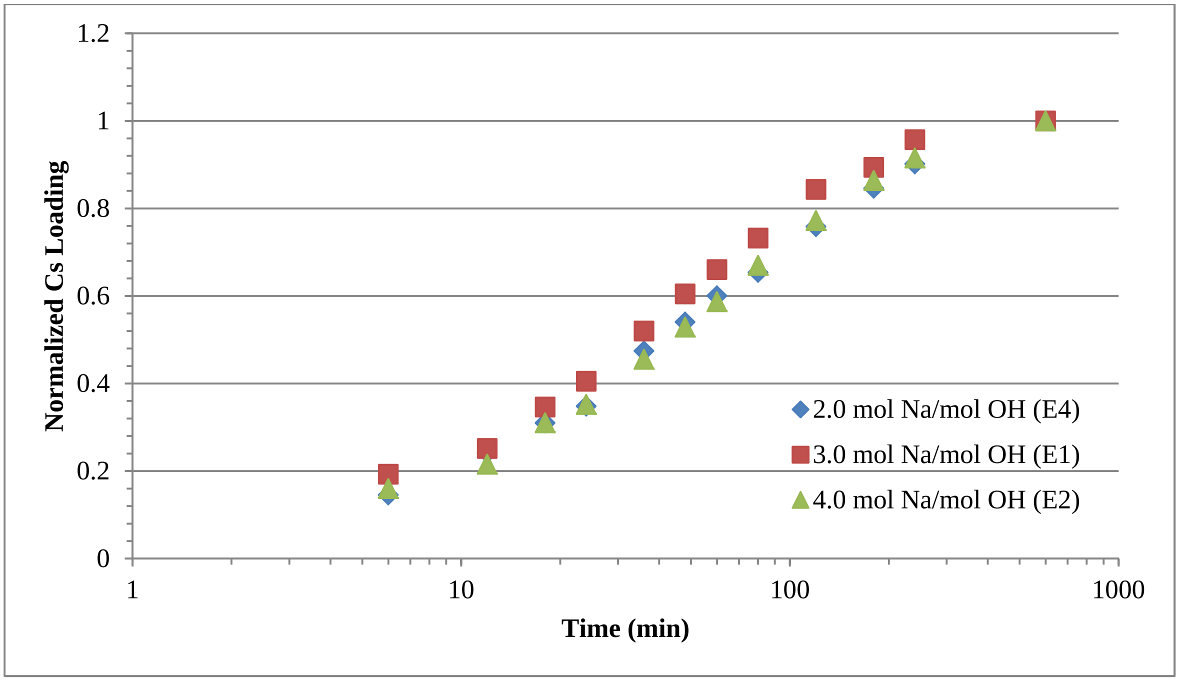


Figure 4.4. Na/OH Ratio Impact on Kinetics of Column Loading

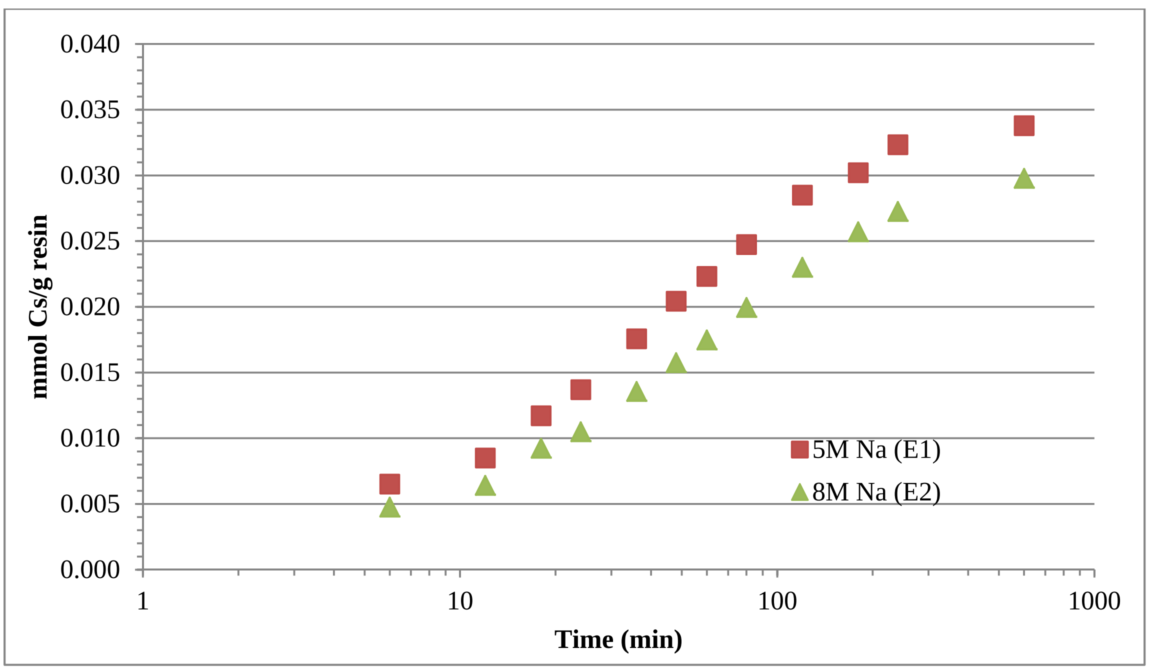


Figure 4.5. Initial Na Impact on Column Loading Capacity

After cycling the resin through four 10-hour loading and elution cycles and a ~336-hour loading cycle, the resin was loaded again for 10 hours with the same conditions as the initial cycle. This is the last test of each series in Table 3.3 (-5), and was used to determine the resin loss of Cs loading kinetics and/or Cs loading capacity. It was found that with the cycles kept at 55°C or lower there did not appear to be any significant resin loss of Cs loading kinetics or Cs loading capacity with the kinetics and loading capacity essentially the same as shown in Figure 4.6. However, the overall loading capacity of the resin was lower than at lower temperatures. For the tests performed continually at 60°C and higher in the 336-hour loading cycle, there was a significant decrease in the resin Cs loading capacity although the initial Cs loading kinetics remained essentially the same, as shown in Figure 4.7 through Figure 4.9. Therefore, in order to avoid a resin loading capacity decrease, the resin loading temperature should be kept 55°C or lower.

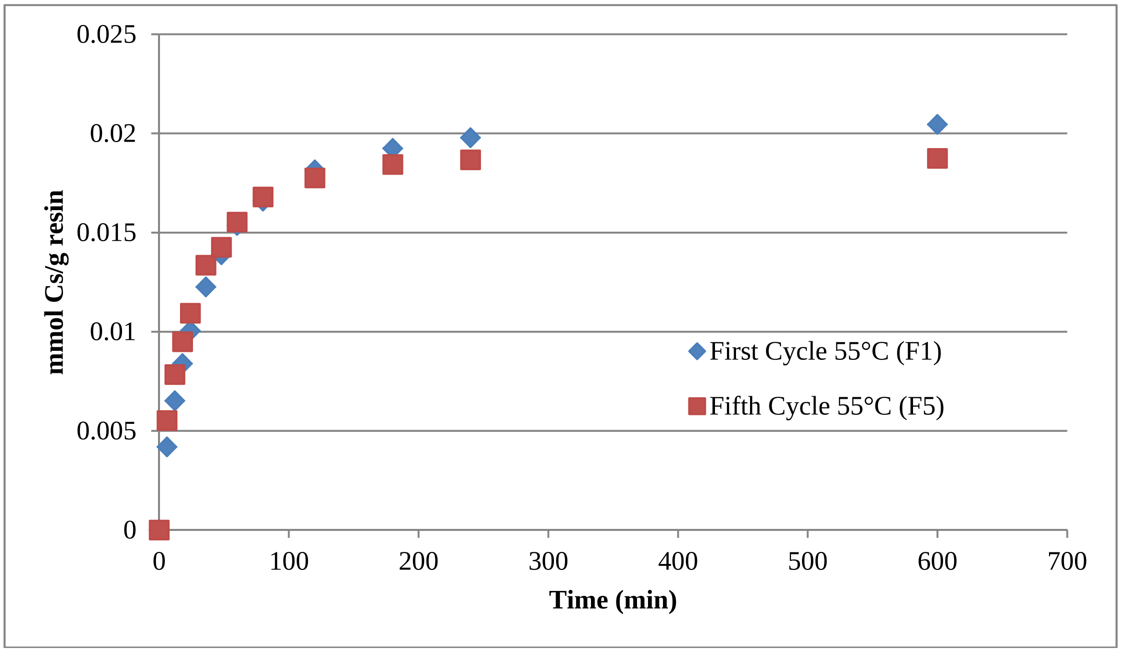


Figure 4.6. First and Fifth Resin Loading Cycles Compared at 55°C

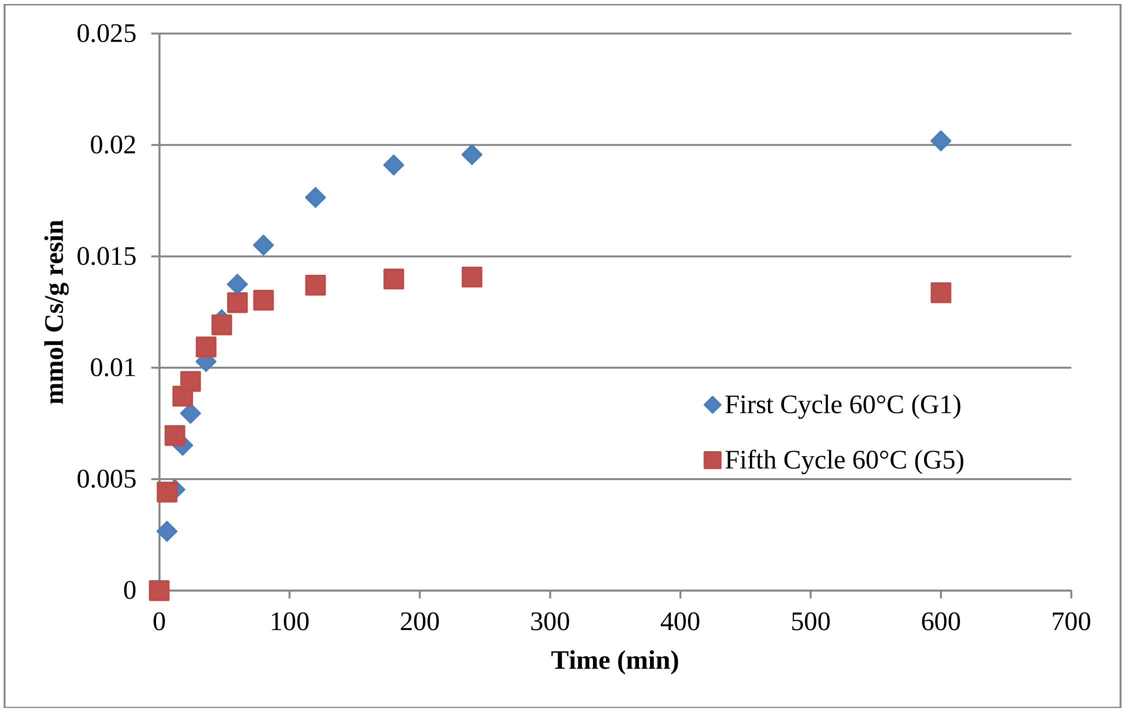


Figure 4.7. First and Fifth Resin Loading Cycles Compared at 60°C

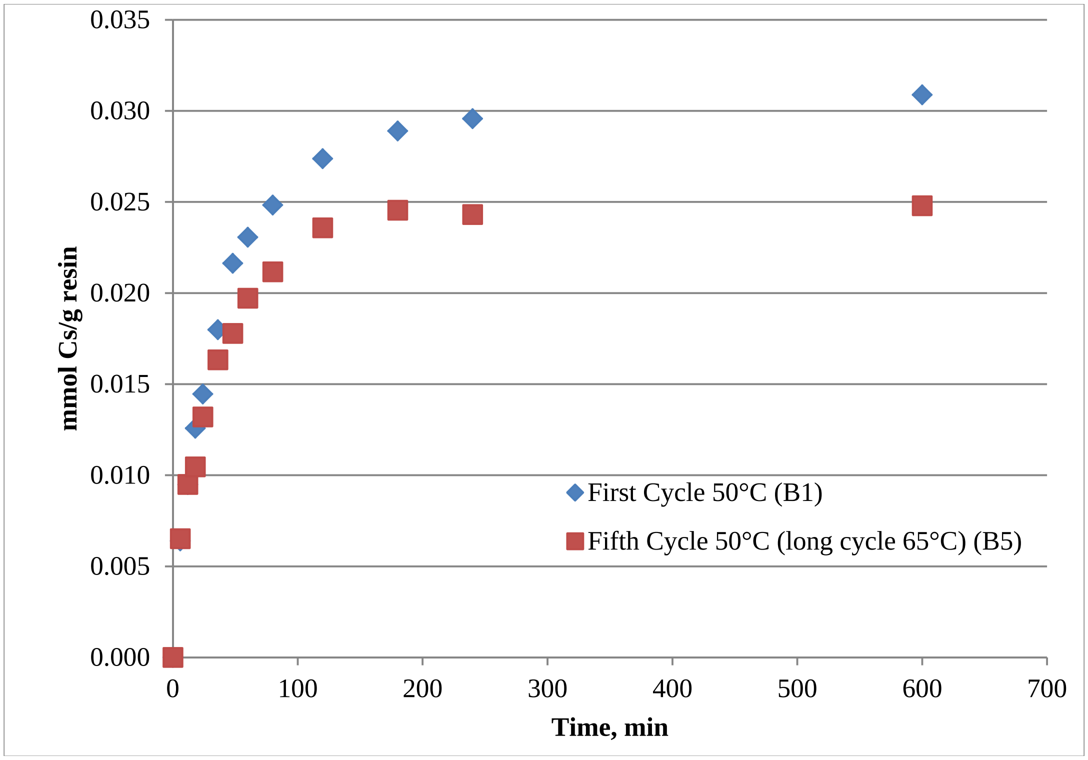


Figure 4.8. First and Fifth Resin Loading Cycles Compared at 50°C with Long Loading Cycle at 65°C

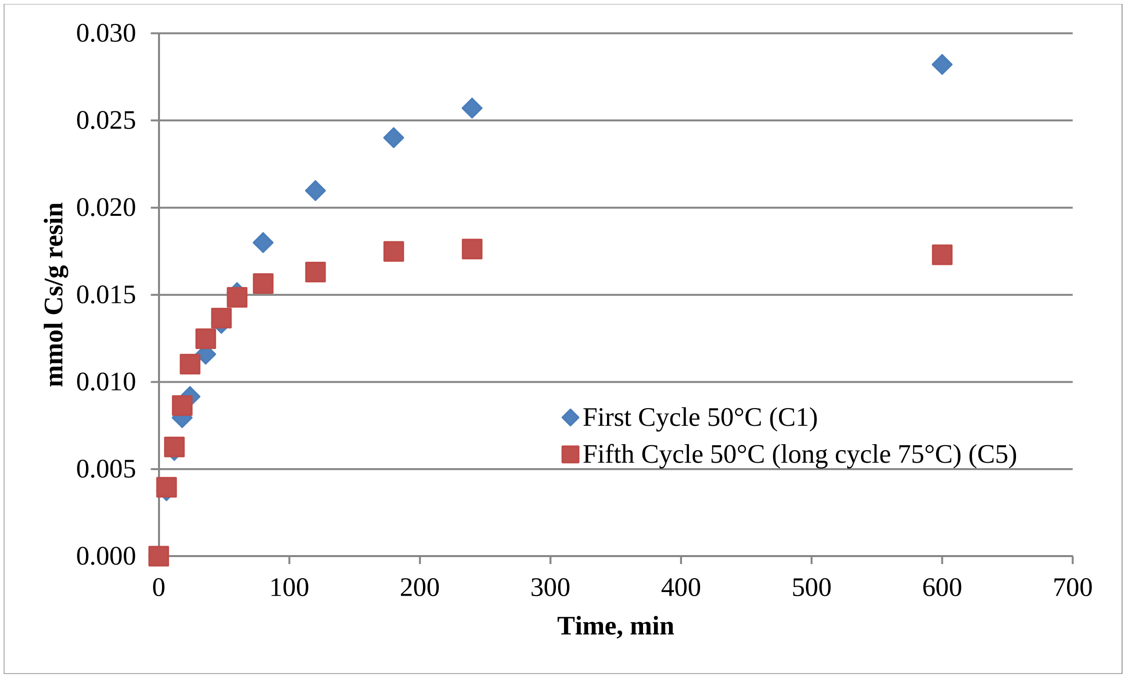


Figure 4.9. First and Fifth Resin Loading Cycles Compared at 50°C with Long Loading Cycle at 75°C

4.2 Impacts of Elevated Temperature on Resin Loading

Resin was loaded at a very low flow rate (~5mL/h) for ~336 hours at a variety of elevated temperatures. These tests were designated as -4B in all of the series of tests. Samples were taken periodically throughout the test to determine the cesium uptake curve. These tests were all performed using 8 M Na and 4 M OH simulants.

Testing for these extended times at elevated temperatures showed that the resin degrades above 45°C, and above 60°C it did not load at all (see Figure 4.10). It was observed that the resin disintegrated at 75°C and partially disintegrated at 65°C, which caused the column to plug during both tests after about 14 days.

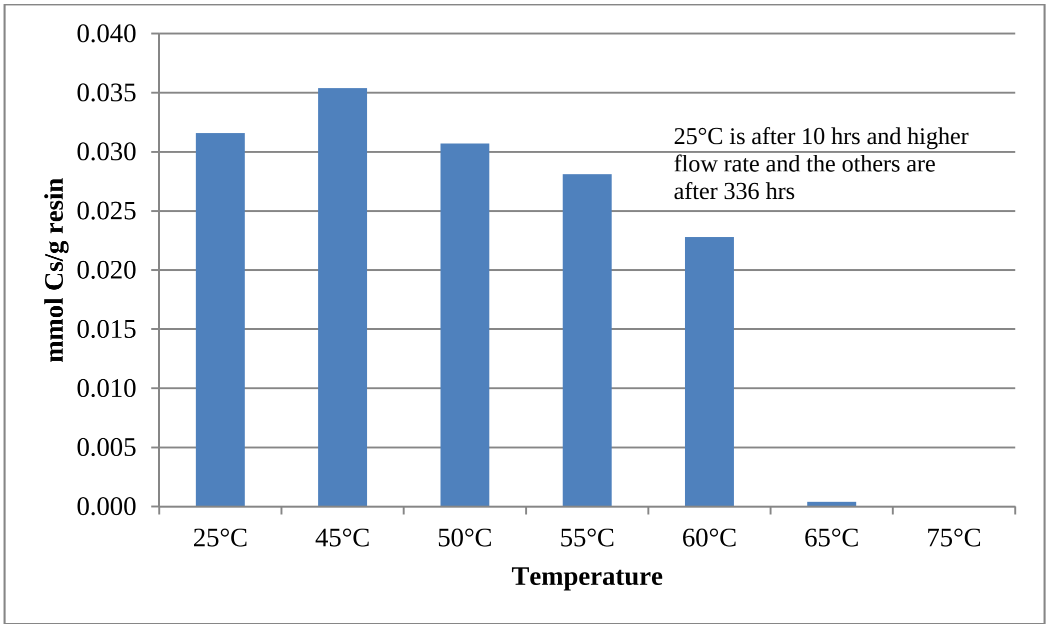


Figure 4.10. Resin Degradation During Extended Flow Testing

After the elevated temperature extended flow testing, the 65°C and 75°C columns were dismantled and observed for resin degradation and precipitates. The resin in the 75°C column (C4B) appeared to be significantly more degraded than the resin in the 65°C column (B4B). The B4B resin was free-flowing and loose as shown in Figure 4.11. The column was initially loaded with 1.8 mL of resin and about 1.55 mL remained after testing. The bottom column support o-ring was stuck to the column glass. A small amount of resin and a white crystalline looking material was on top of the o-ring and wedged between the bed support and the column glass as shown in Figure 4.12. The lower bed support was removed and the debris stuck to it was washed into a glass 20 mL vial with DI water. The material stuck on the column wall, as shown in Figure 4.13, was washed into the same vial. This debris was analyzed through optical microscopy, polarized light microscopy (PLM), and scanning electron microscopy-energy dispersive scattering (SEM-EDS) and is shown in Figure 4.14 through Figure 4.18. Palladium was added to the sample to assist in the EDS analysis. The white crystalline material appeared to be sodium aluminate that had crystallized from the simulant being fed through the column based on the EDS analysis.

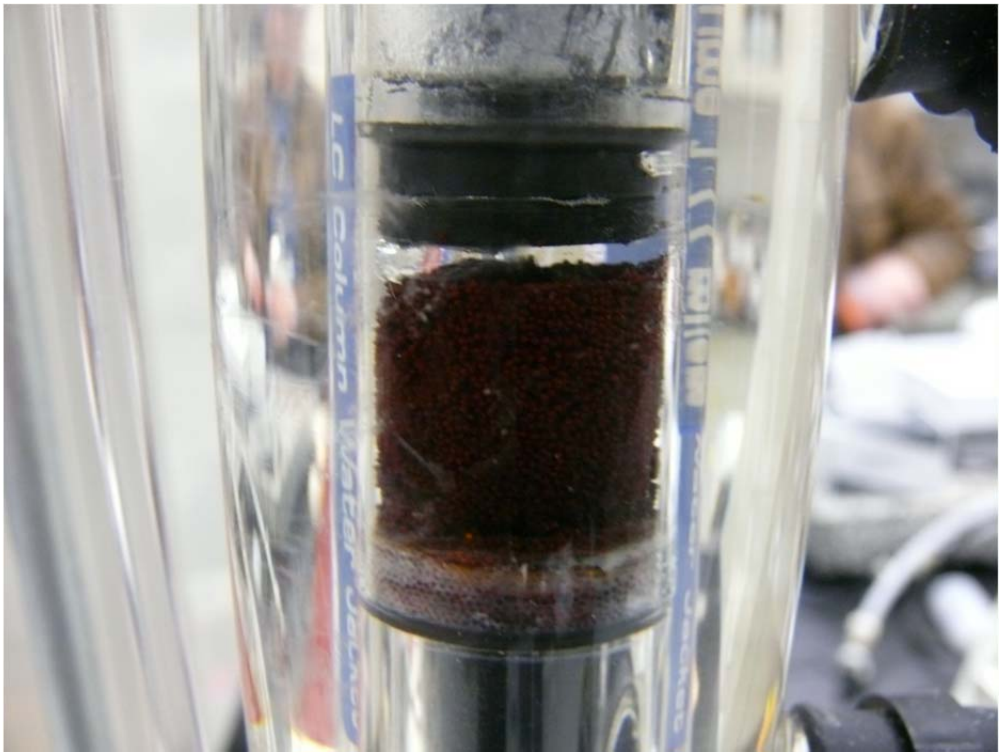


Figure 4.11. Column B Resin After Testing at 65°C

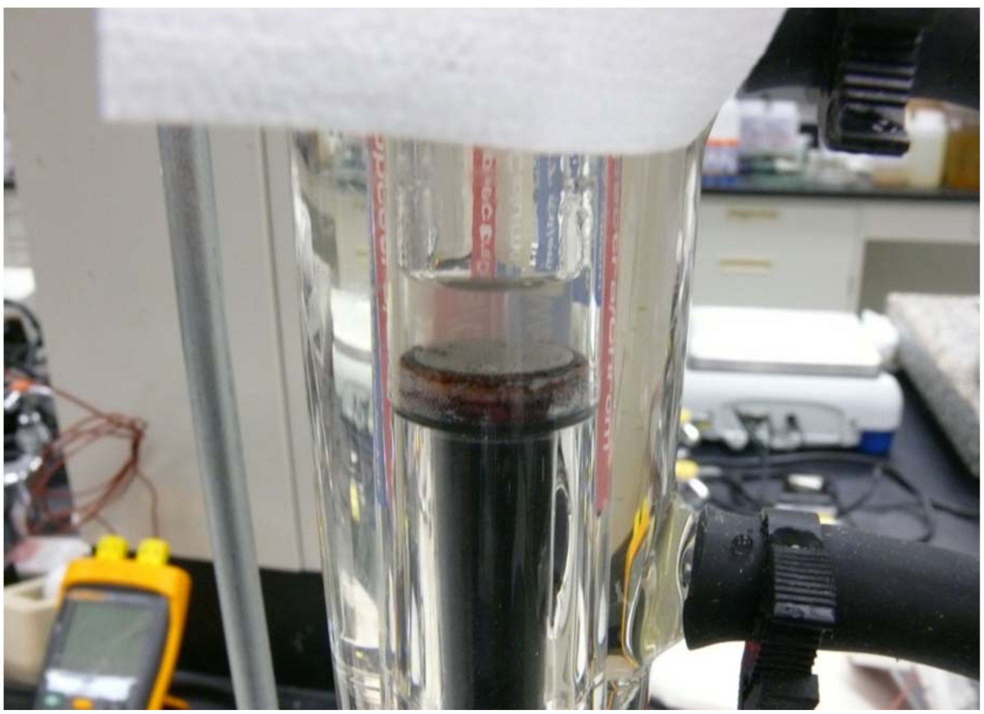


Figure 4.12. White Crystalline Material on Top of the O-Ring and Wedged Between the Bed Support and the Column B Glass

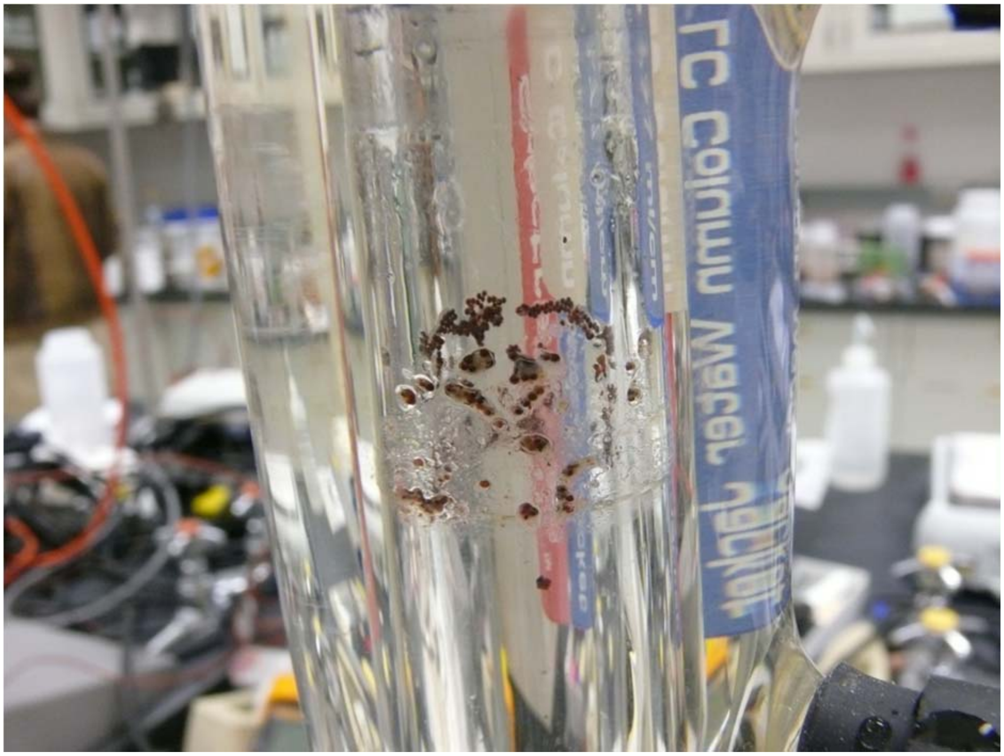


Figure 4.13. Material Stuck on the Column B Wall After Testing at 65°C

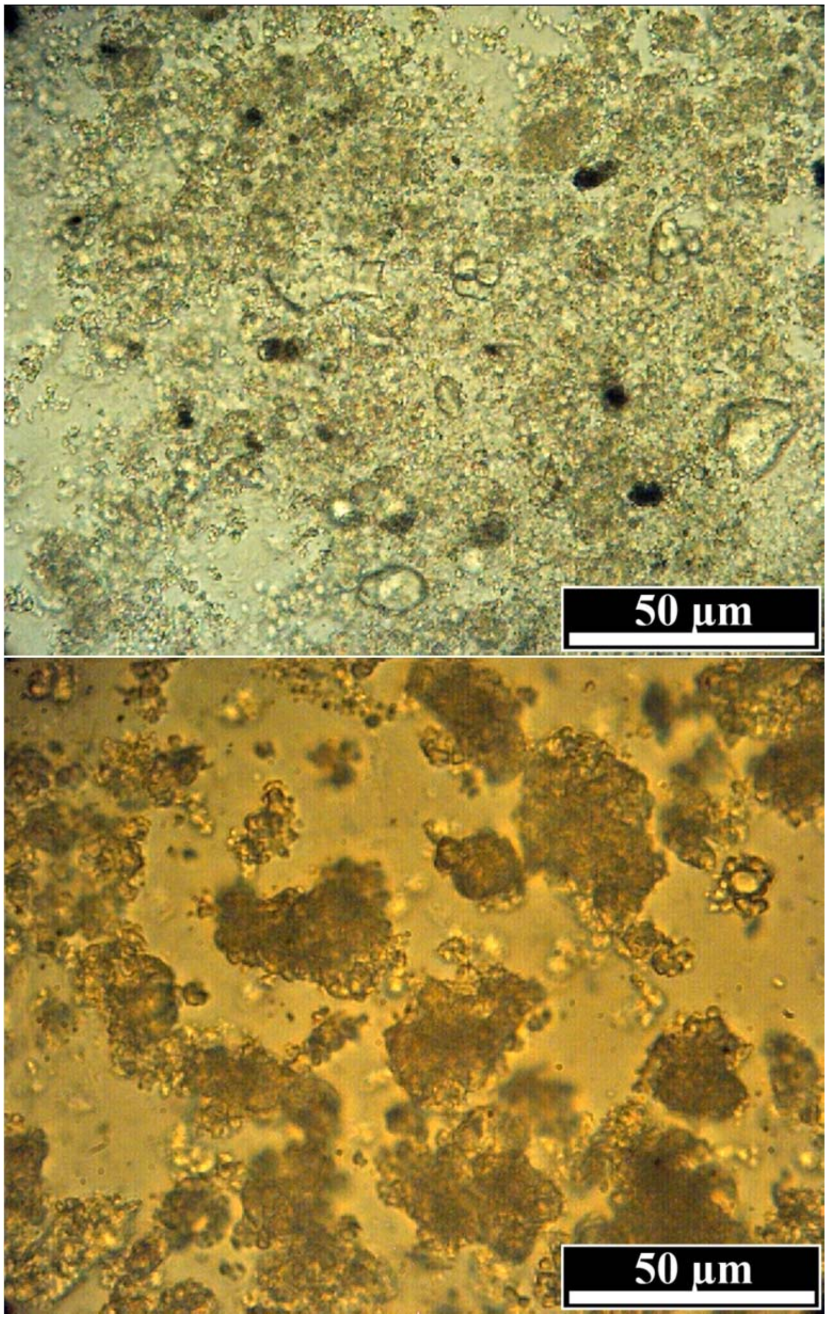


Figure 4.14. Material Washed from the Plugged Resin Bed in Test B (65°C) from Optical Microscopy--500X (top) and 1000X (bottom)

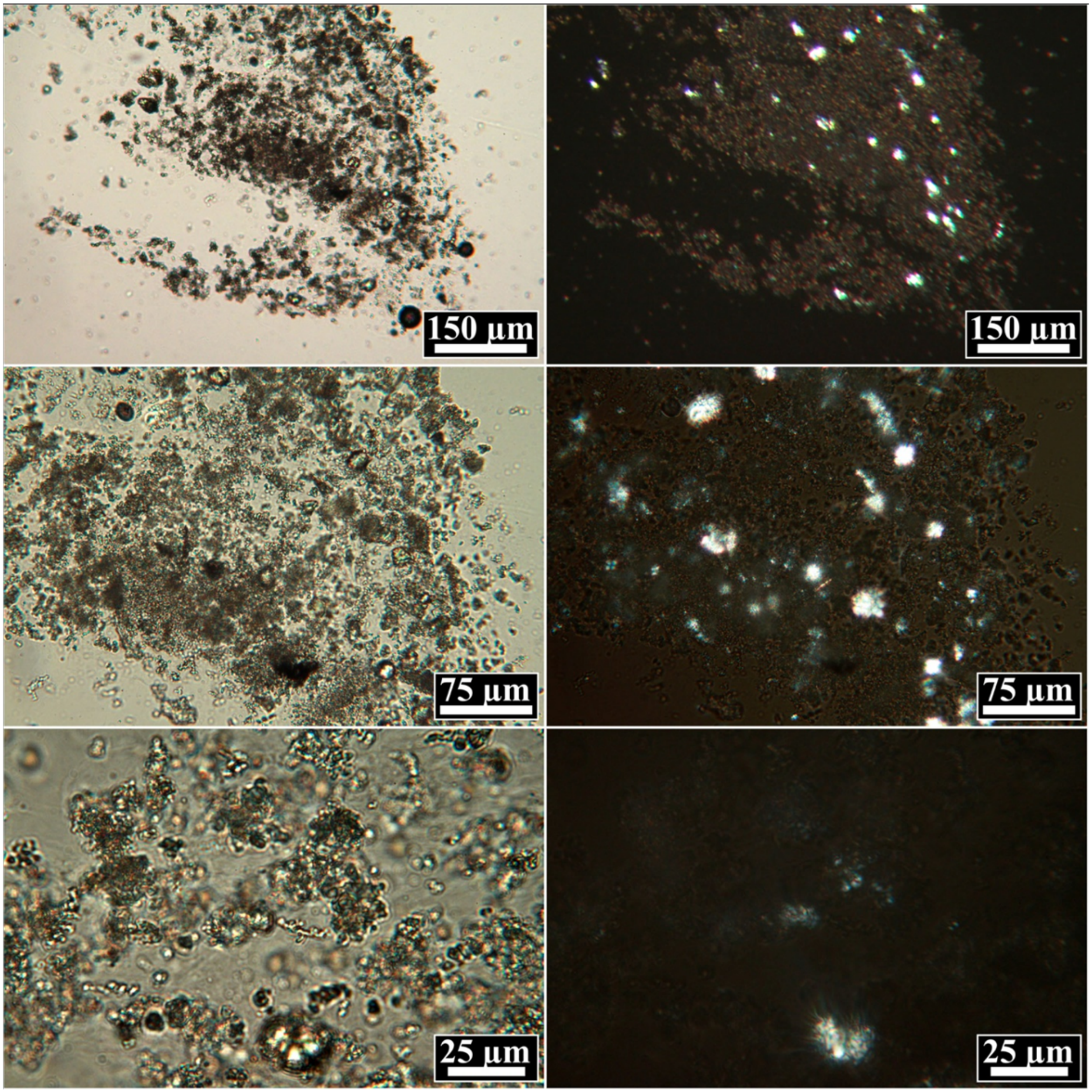
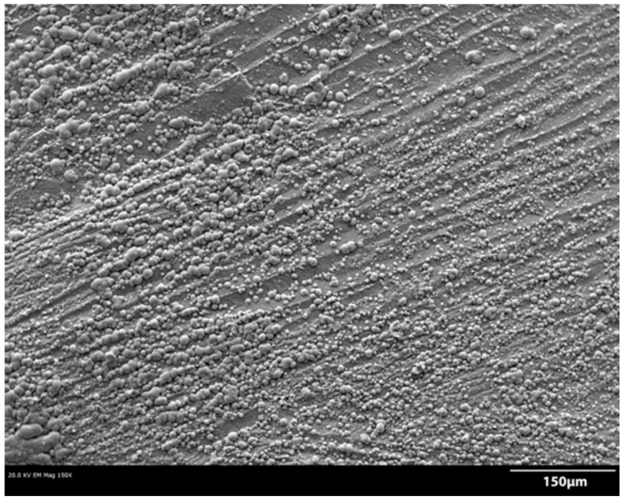
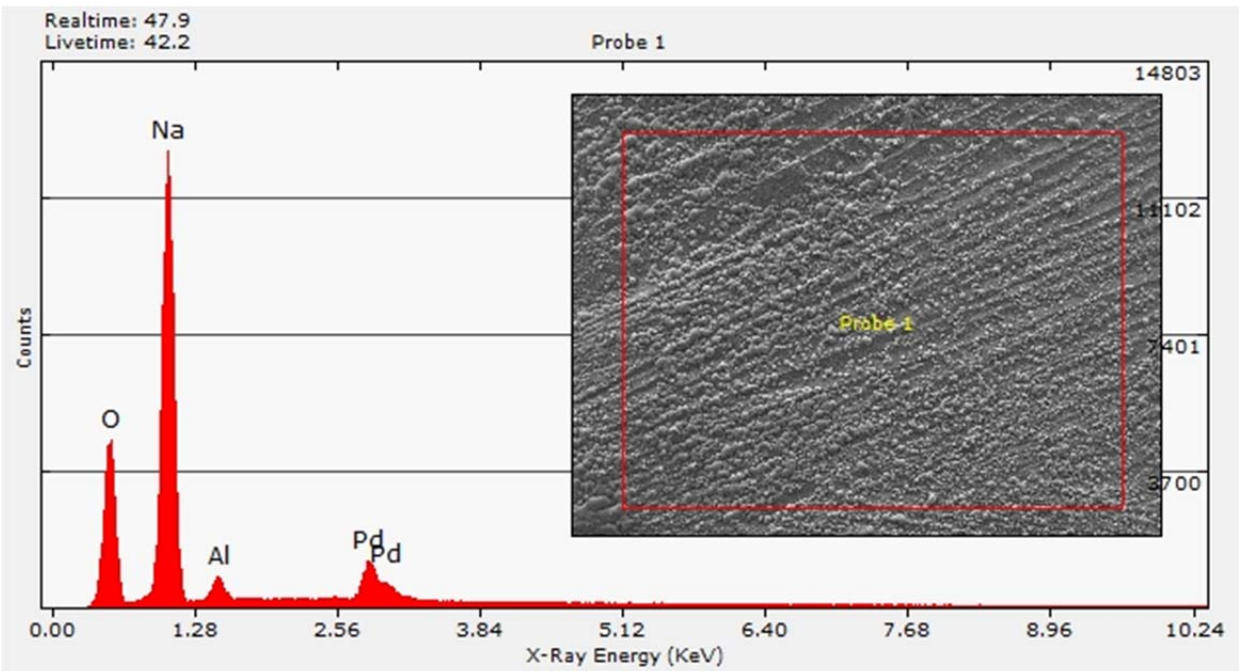


Figure 4.15. Material Washed from the Plugged Resin Bed in Test B (65°C) from PLM

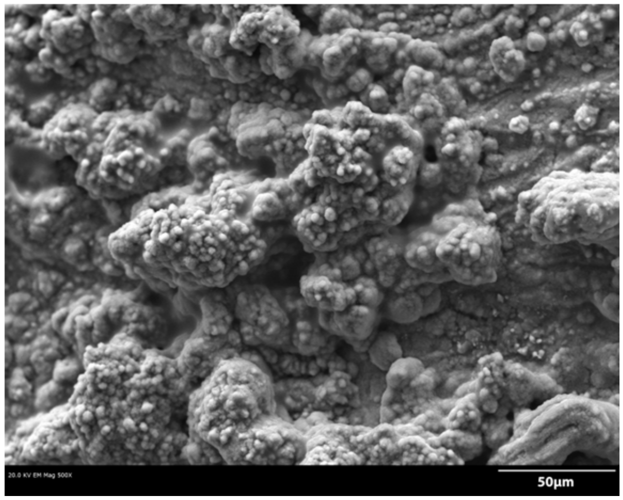




Quantitative Results for Probe 1
Analysis: Bulk Method: Standardless
Acquired 27-Sep-2011, 20.0 KeV @10 eV/channel

Element	Weight %	Std. Dev.	Atomic %
O	30.31	1.04	40.36
Na	59.61	1.36	55.23
Al	4.05	0.98	3.20
Pd	6.03	1.07	1.21
Total	100.00		

Figure 4.16. Material Washed from the Plugged Resin Bed in Test B (65°C) from SEM-EDS (150 µm scale)



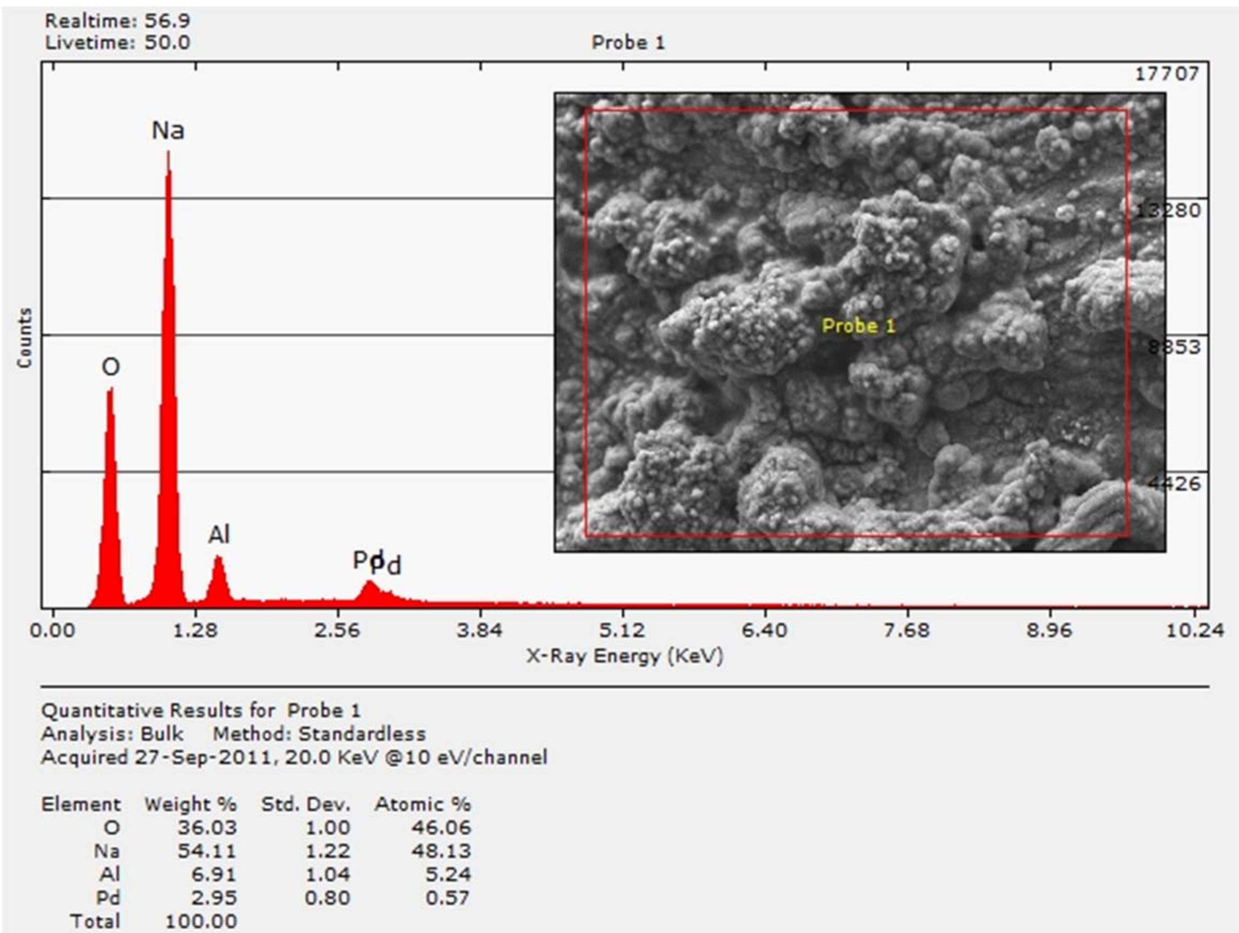
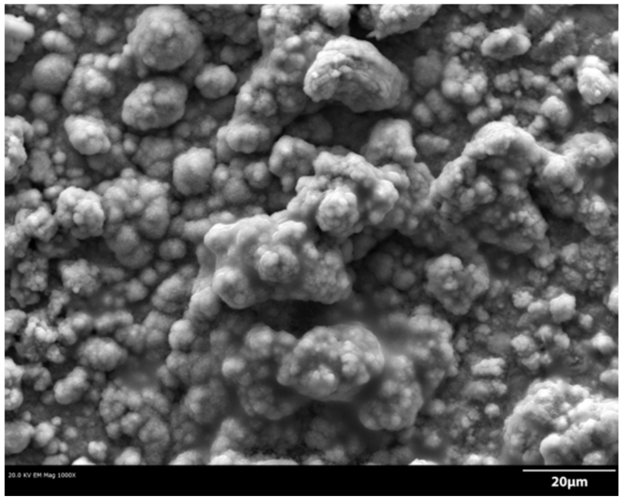
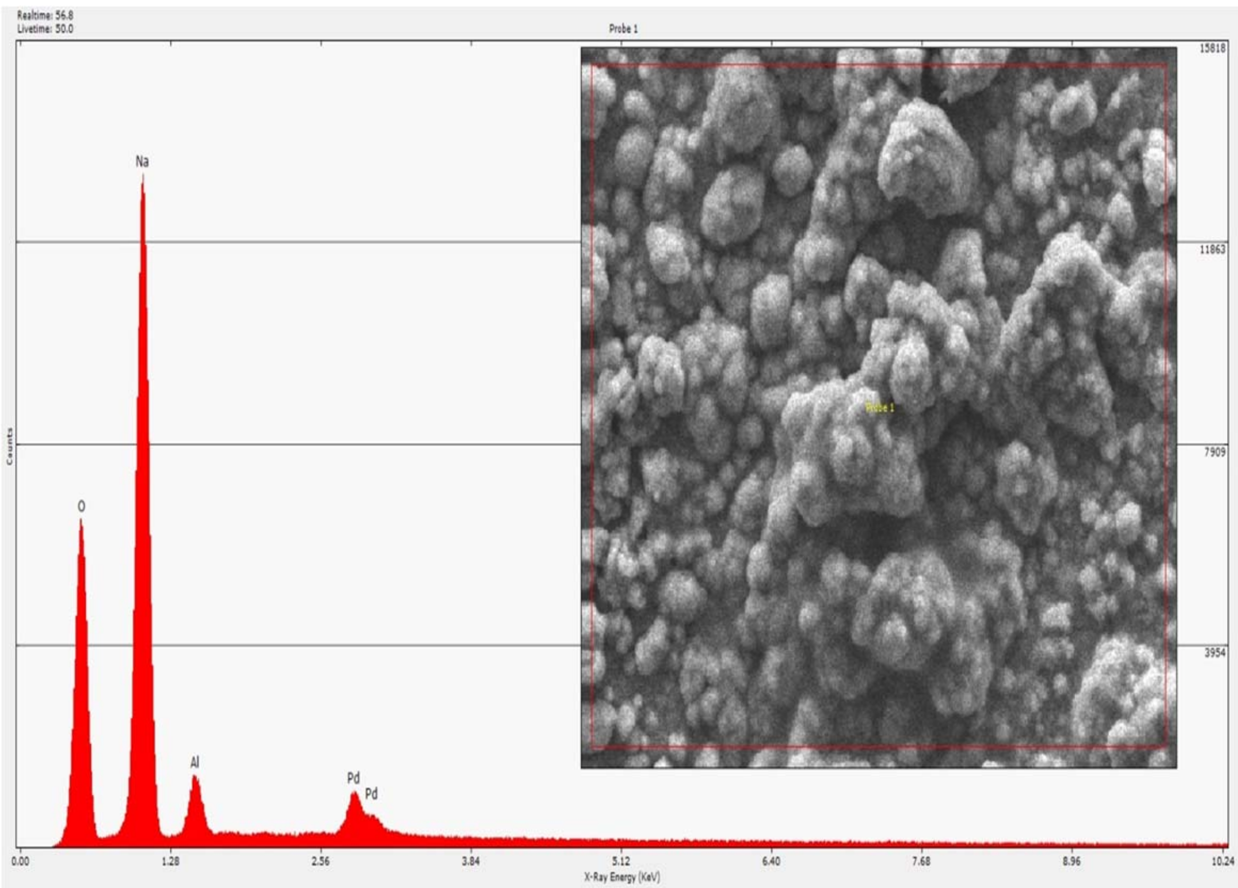


Figure 4.17. Material Washed from the Plugged Resin Bed in Test B (65°C) from SEM-EDS (50 µm scale)





Quantitative Results for Probe 1
Analysis: Bulk Method: Standardless
Acquired 27-Sep-2011, 20.0 KeV @10 eV/channel

Element	Weight %	Std. Dev.	Atomic %
O	35.40	1.01	45.64
Na	54.52	1.24	48.92
Al	6.09	1.07	4.66
Pd	3.99	0.96	0.77
Total	100.00		

Figure 4.18. Material Washed from the Plugged Resin Bed in Test B (65°C) from SEM-EDS (20 µm scale)

In the C4B resin, Figure 4.19 shows how degraded the resin appeared before column removal and Figure 4.20 shows the color of the supernate removed from the column. Only the top 80% was loose and free-flowing with the bottom portion hard-set and stuck to the glass. A Teflon coated metal spatula was used to break this material loose. Once the o-ring was broken loose from the column, the lower bed support was removed. The buildup of material between the bed support and the wall of the column, shown in Figure 4.21, made removing the support very difficult. The column was initially loaded with 1.8 mL of resin with about 1.5 mL remaining after testing. After removal of the lower support, the resin and other debris on the lower support bed were washed into the graduated cylinder with the resin. The total volume of resin and black residue was 1.8 mL. This resin and debris were analyzed with optical microscopy, PLM, and SEM-EDS and are shown in Figure 4.22 through Figure 4.25. Again, the white crystalline material appeared to be sodium aluminate that had crystallized from the simulant being fed through the column based on the EDS analysis.

After washing the lower bed support, there was still significant debris stuck to the outside and top edge of the support. A metal spatula was used to scrape this material from the support. The resulting debris was washed into another glass vial and analyzed using the same methods. The material was very dark, almost black, in color. These results are shown in Figure 4.26 through Figure 4.32. The presence of Si and Ca in the solids analyzed by EDS suggests that the glass column was degraded by the high concentration, high temperature caustic solution over an extended period of time.

The material that was left on the inside of the column (shown in Figure 4.33) was washed into a third vial and analyzed similarly, with the results shown in Figure 4.34. This appears to be a combination of resin and sodium aluminate again; however, EDS was not performed on this sample to confirm this.

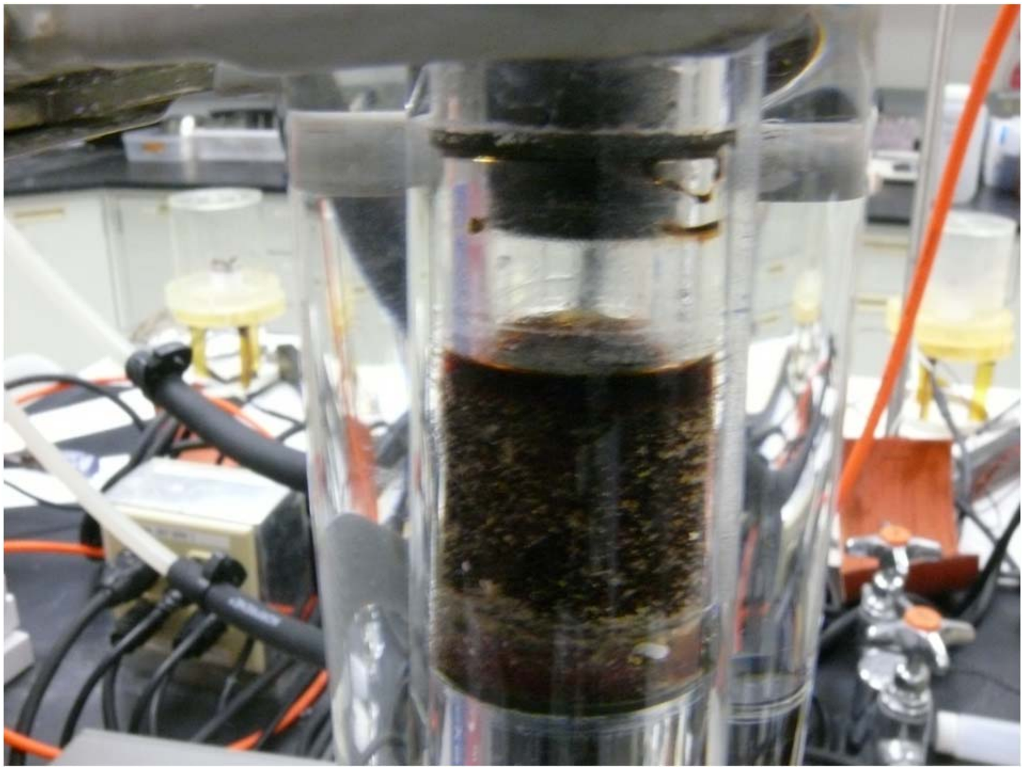


Figure 4.19. Resin After Testing of Column C at 75°C

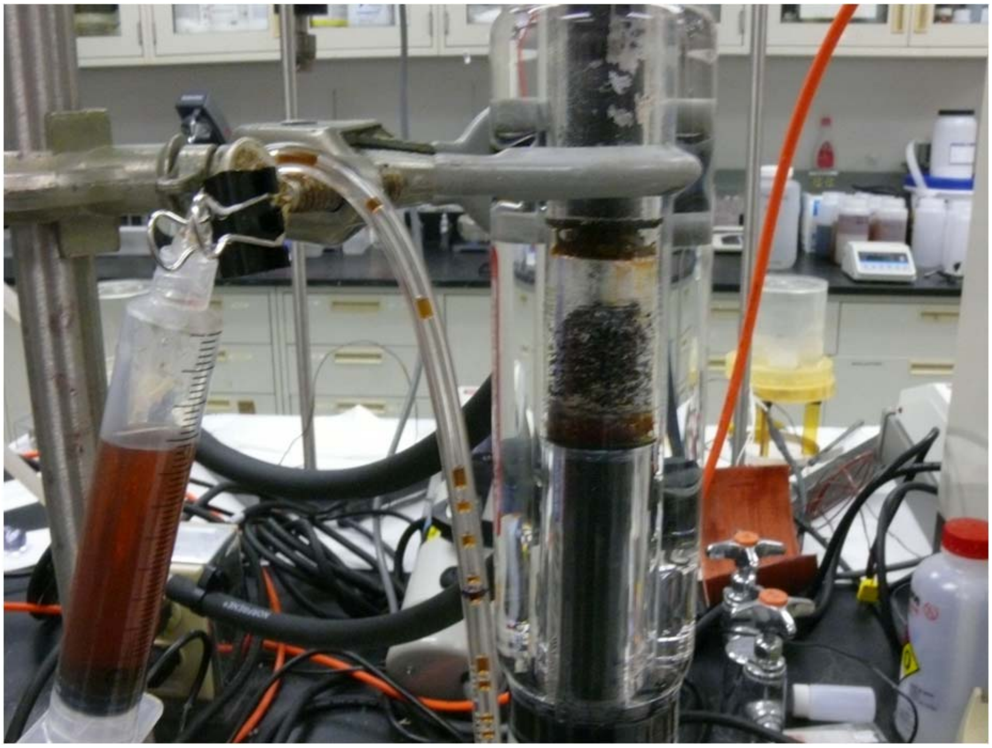


Figure 4.20. Supernate Removed from Column C after Testing at 75°C

Figure 4.21. Material Between Column C Wall and Bed Support

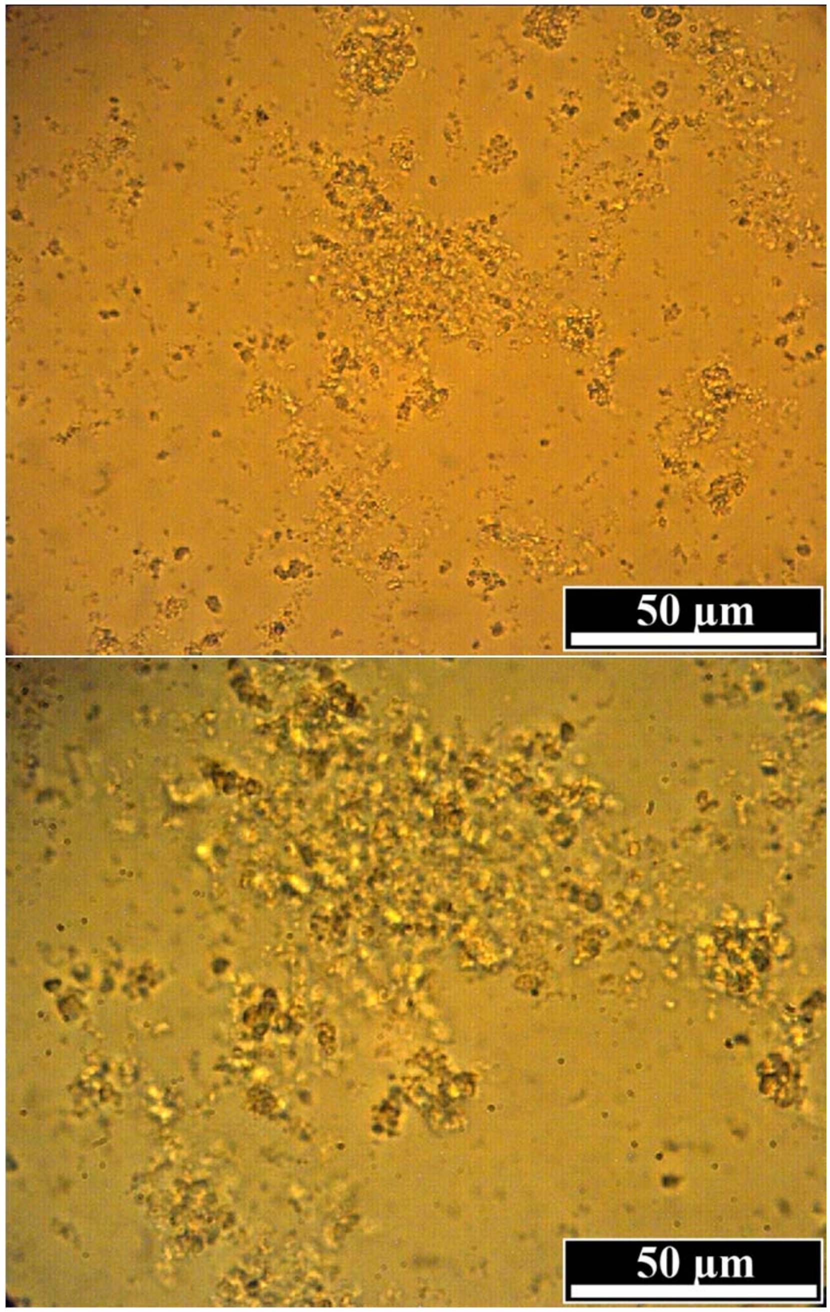


Figure 4.22. Material Washed from the Plugged Resin Bed in Test C (75°C) from Optical Microscopy--500X (top) and 1000X (bottom)

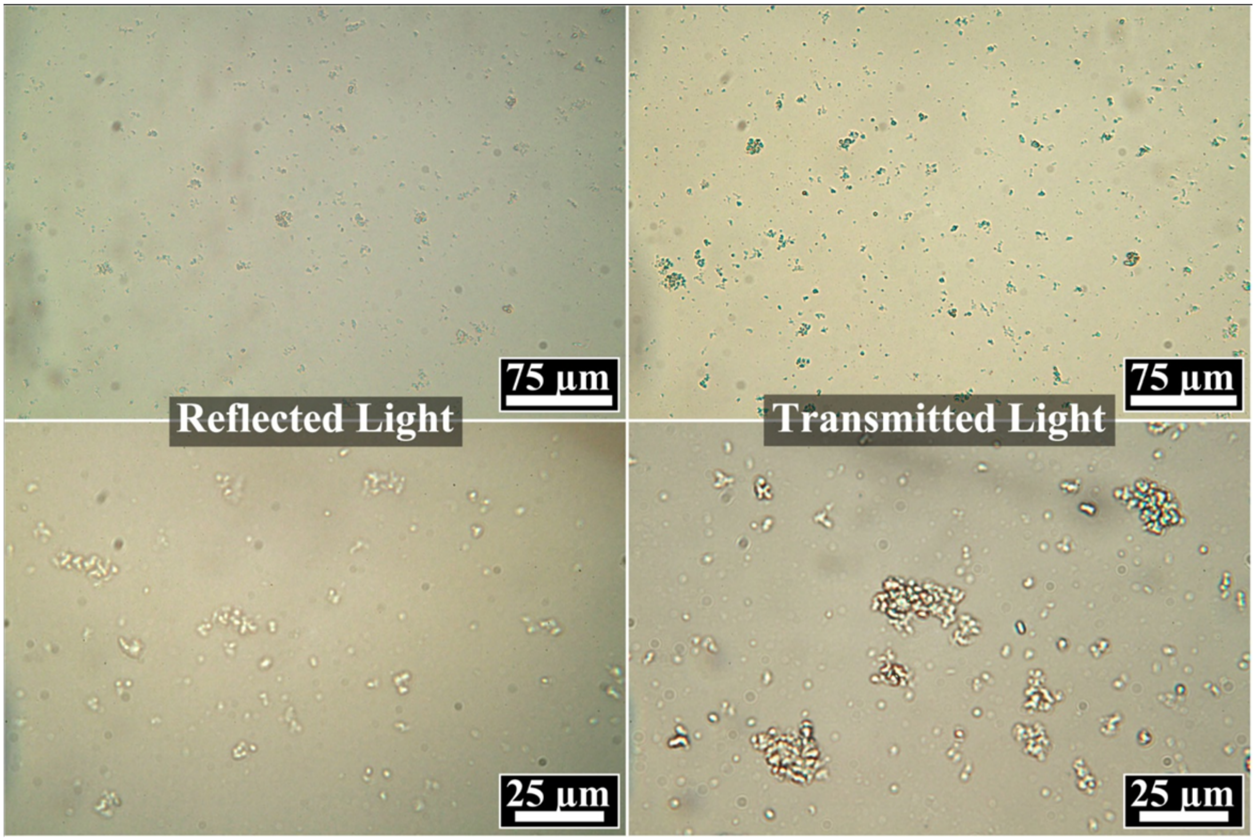


Figure 4.23. Material Washed from the Plugged Resin Bed in Test C (75°C) from PLM

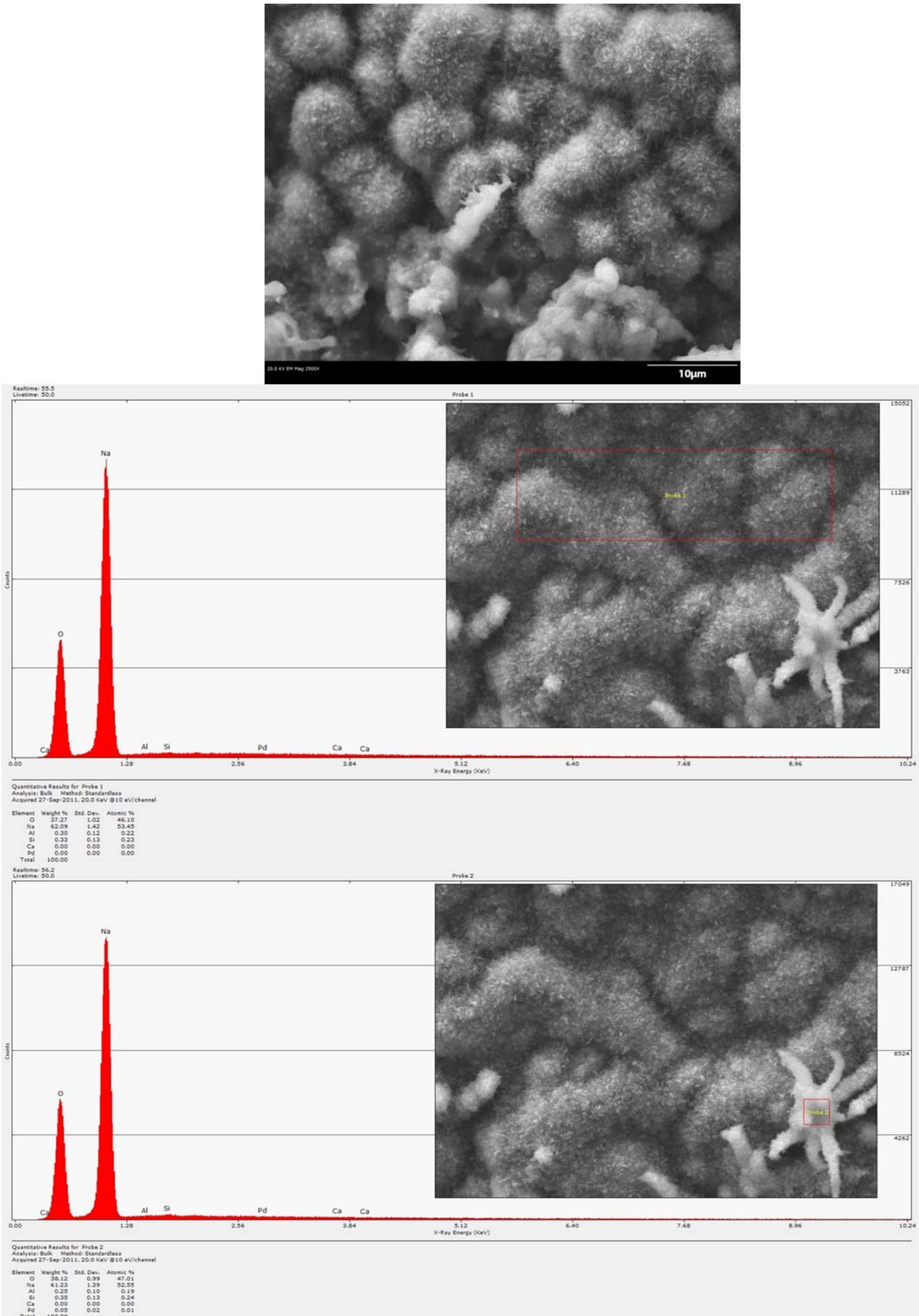


Figure 4.24. Material Washed from the Plugged Resin Bed in Test C (75°C) from SEM-EDS (10 µm)

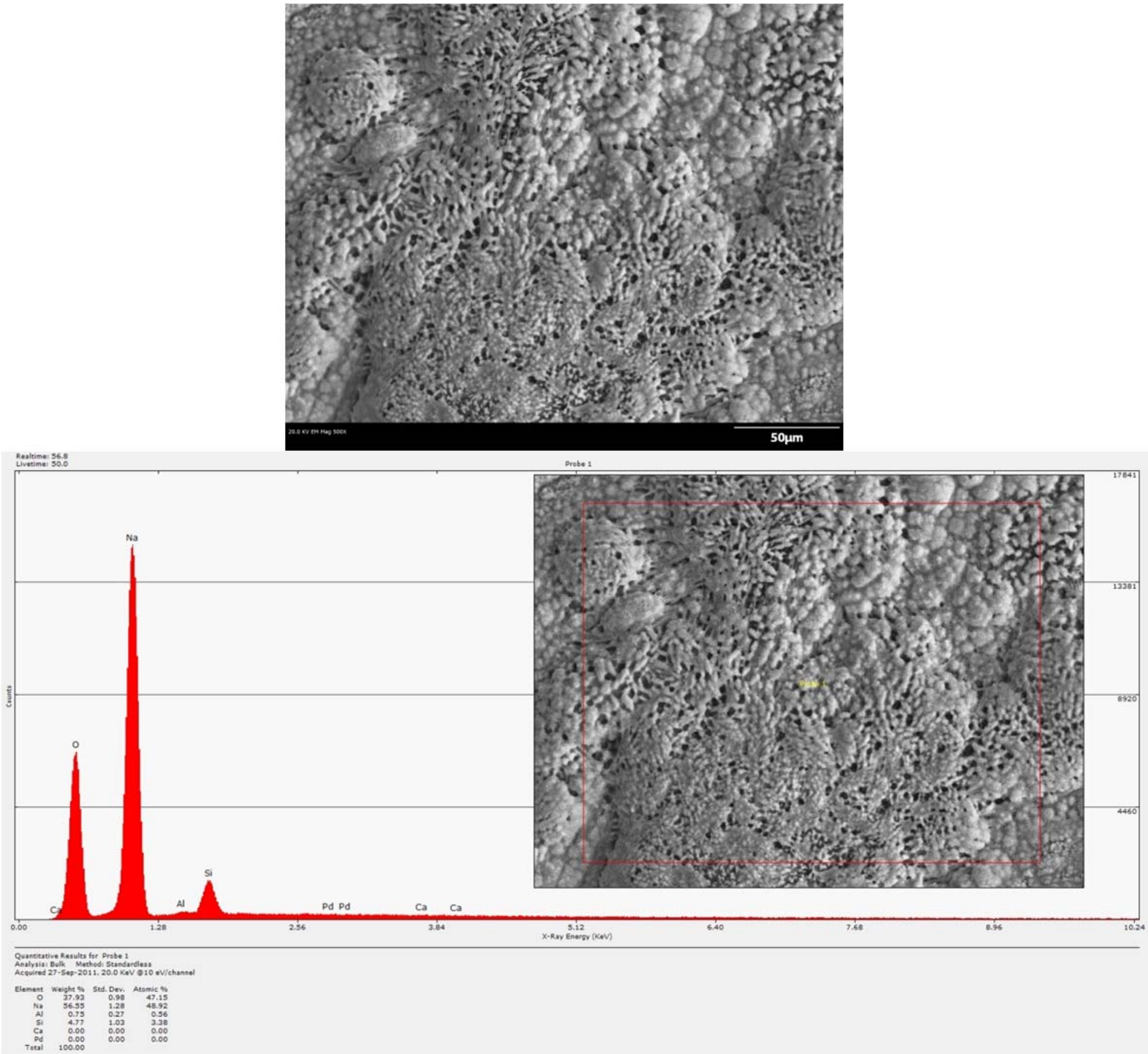


Figure 4.25. Material Washed from the Plugged Resin Bed in Test C (75°C) from SEM-EDS (20 µm)

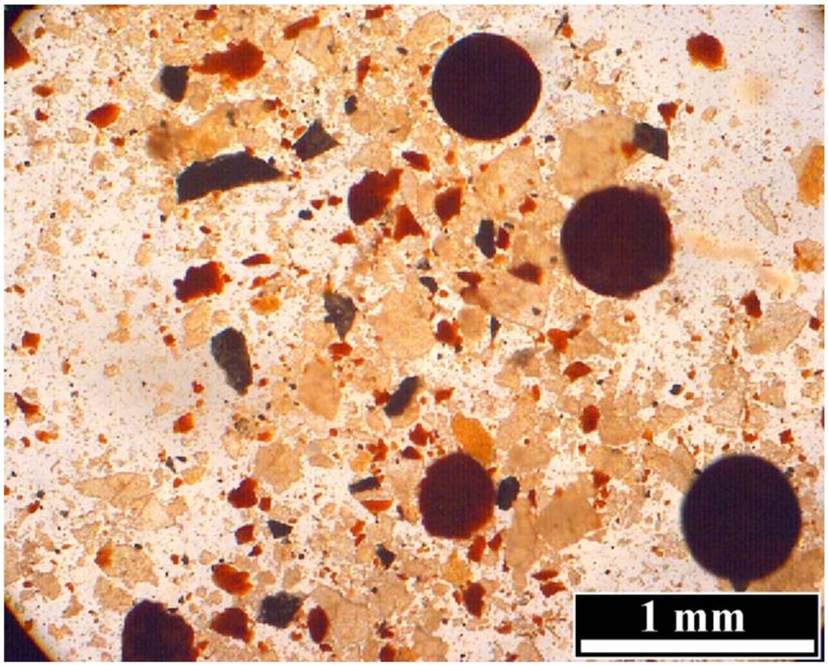


Figure 4.26. Sample Scraped and Washed from Lower Column Support after Test C (75°C) from Optical Microscopy—70X

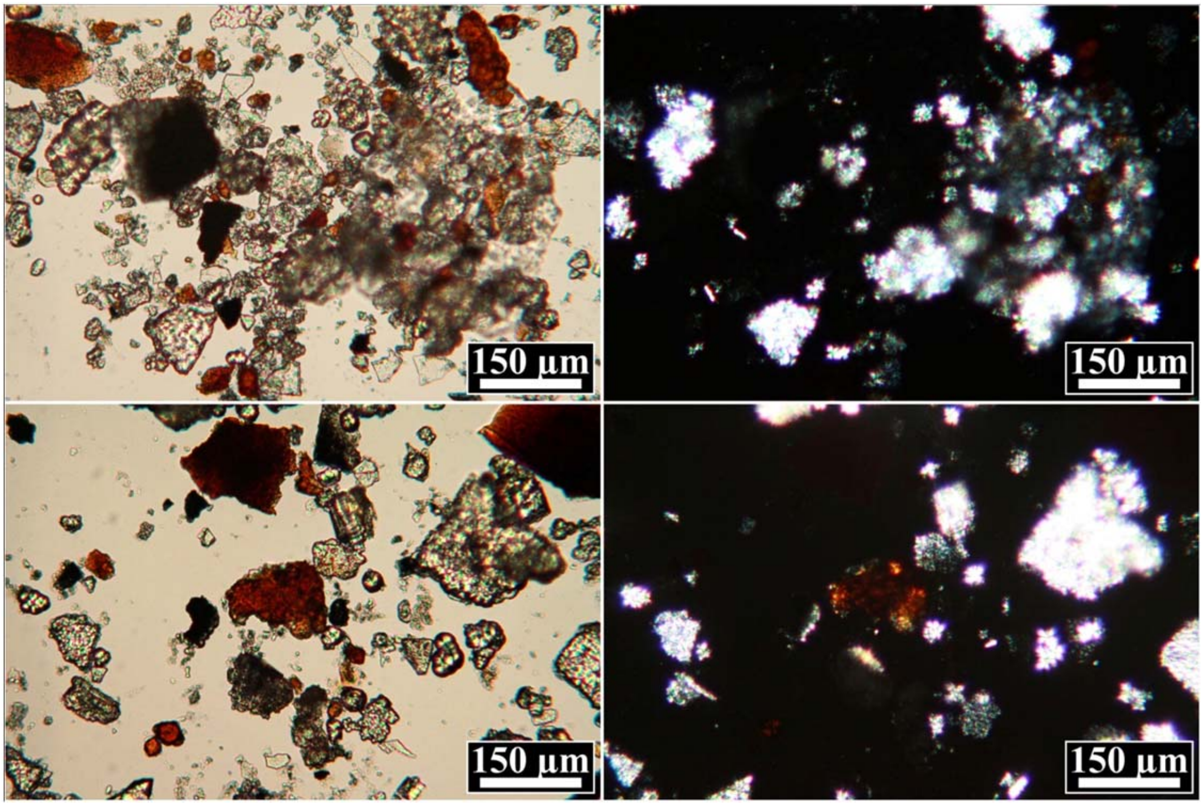


Figure 4.27. Sample Scraped and Washed from Lower Column Support after Test C (75°C) from PLM

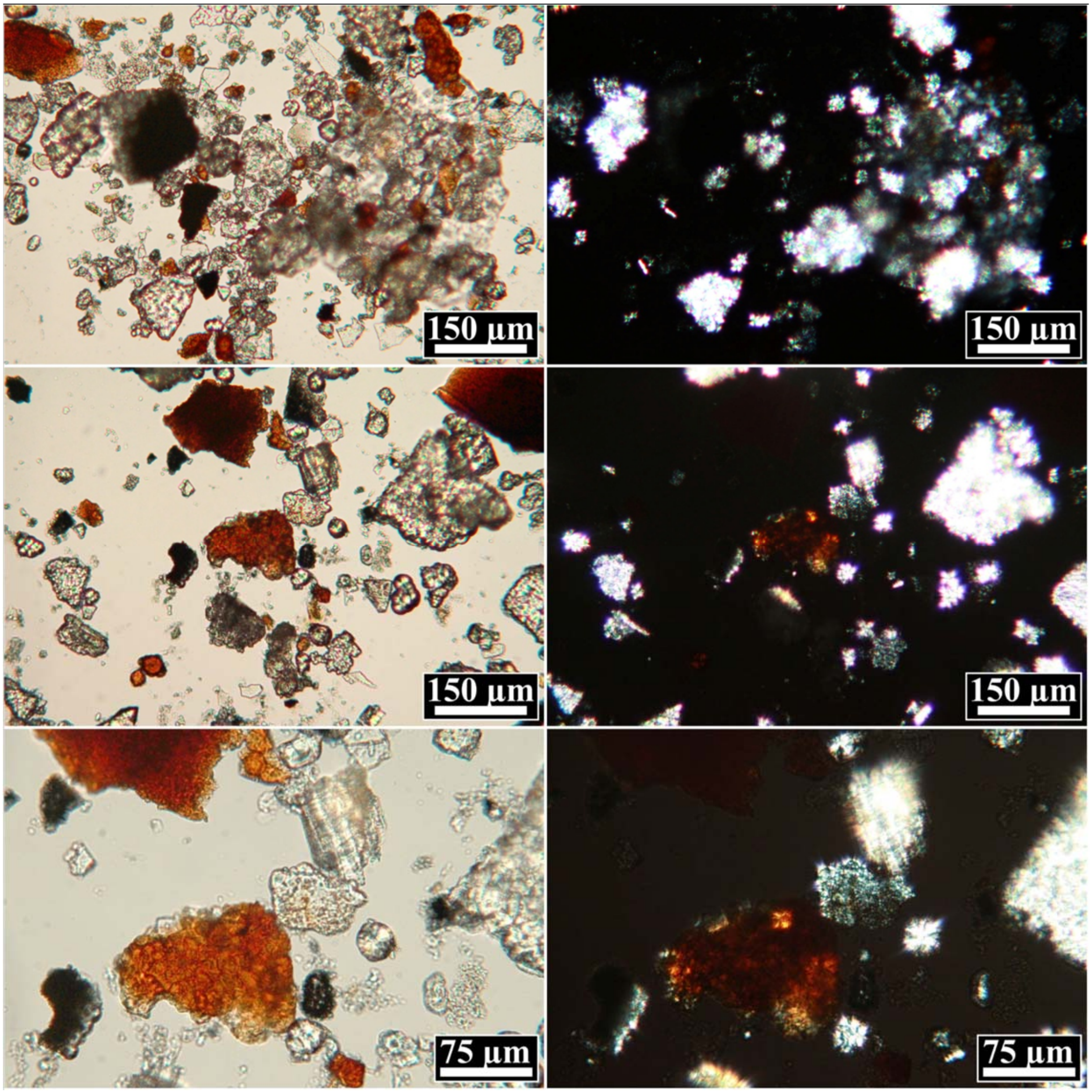
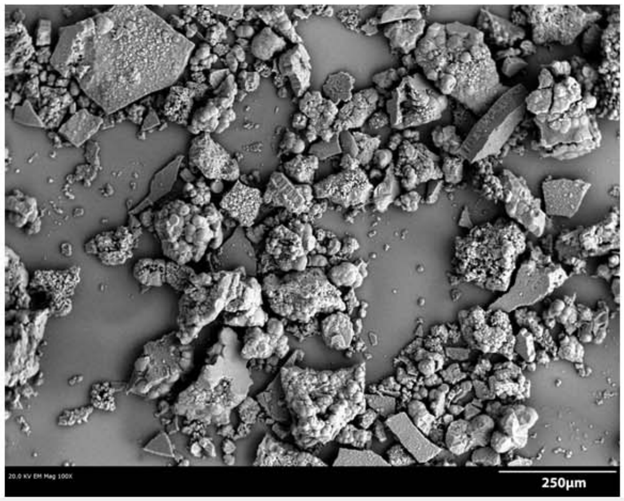


Figure 4.28. Sample Scraped and Washed from Lower Column Support after Test C (75°C) from Trans PLM



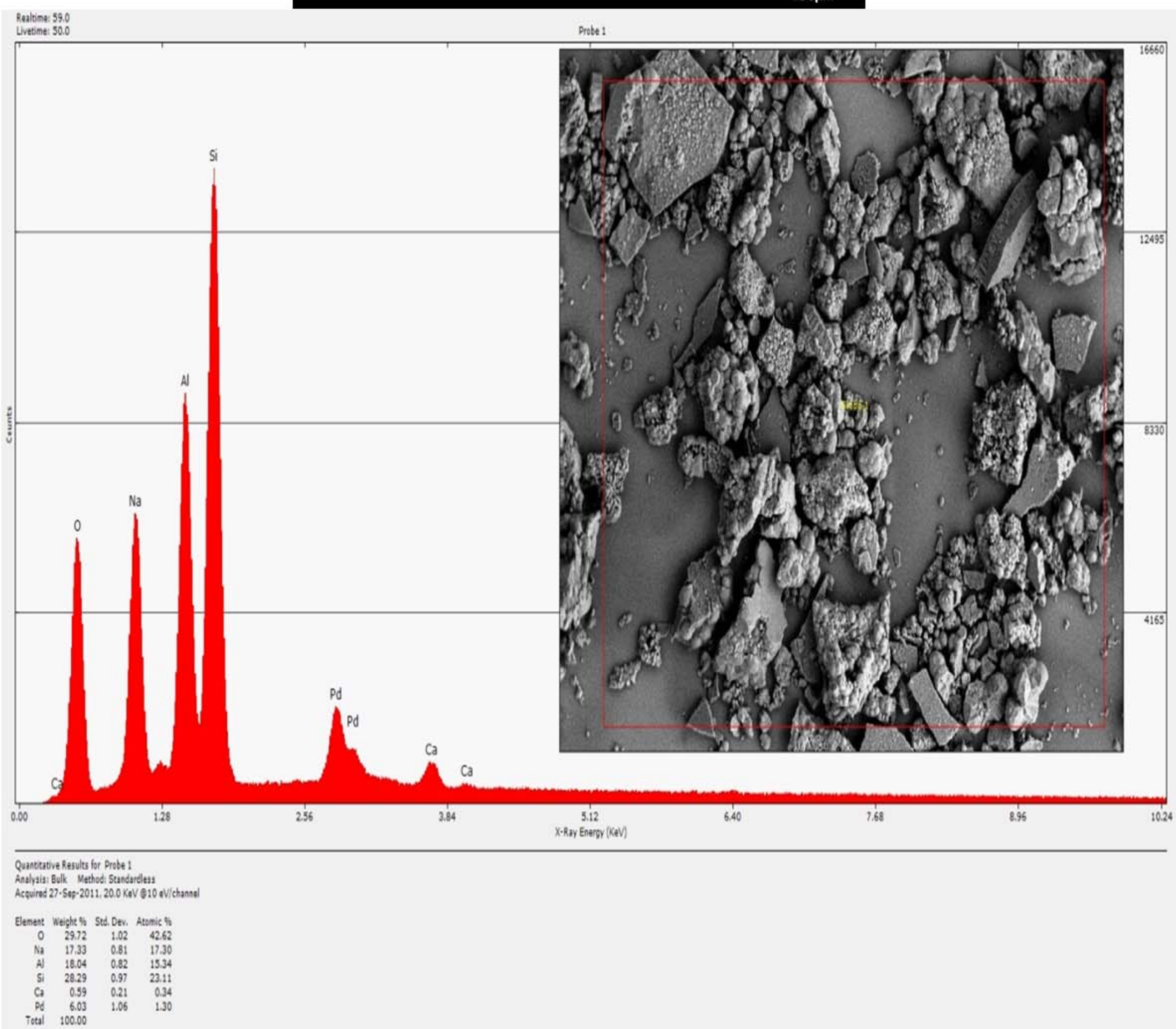
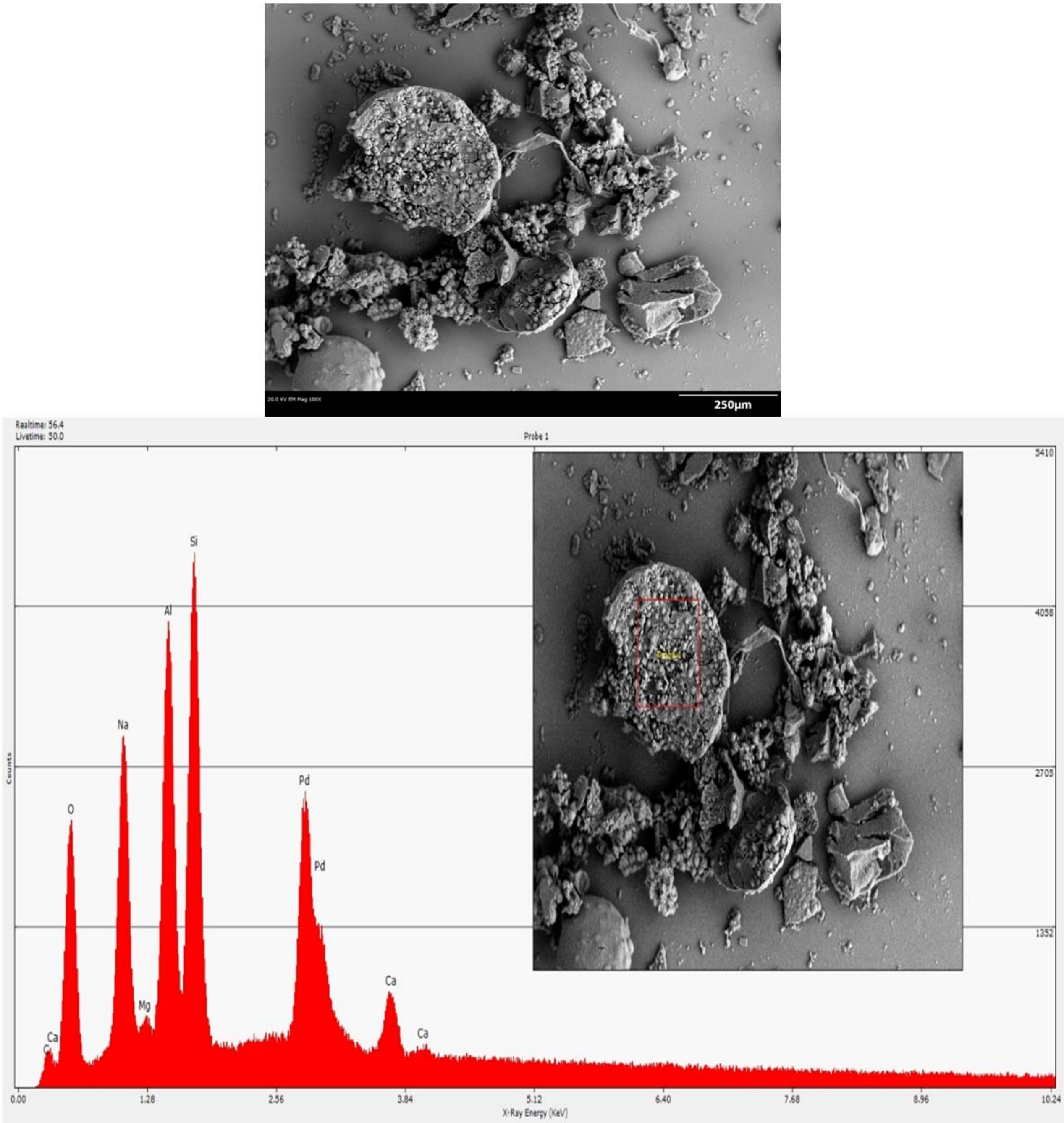


Figure 4.29. Sample Scraped and Washed from Lower Column Support after Test C (75°C) from SEM-EDS (large area at 250 µm)



Quantitative Results for Probe 1
Analysis: Bulk Method: Standardless
Acquired 27-Sep-2011, 20.0 KeV @10 eV/channel

Element	Weight %	Std. Dev.	Atomic %
C	2.99	0.86	6.04
O	23.29	1.01	35.35
Na	18.91	0.88	19.98
Mg	2.77	0.78	2.77
Al	17.53	0.83	15.78
Si	18.08	0.85	15.63
Ca	1.85	0.57	1.12
Pd	14.58	0.75	3.33
Total	100.00		

Figure 4.29. Sample Scraped and Washed from Lower Column Support after Test C (75°C) from SEM-EDS (small spot at 250 µm)

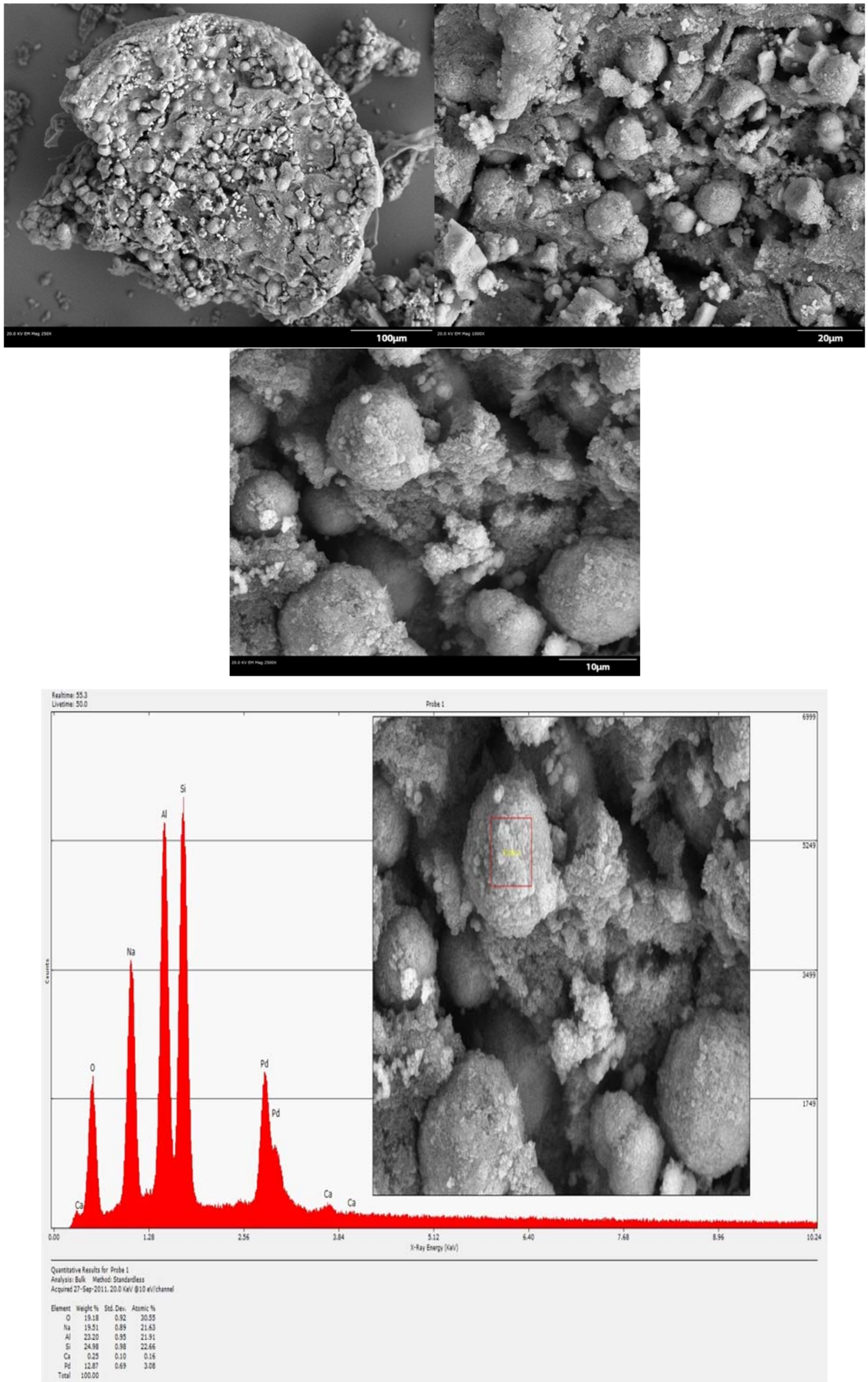
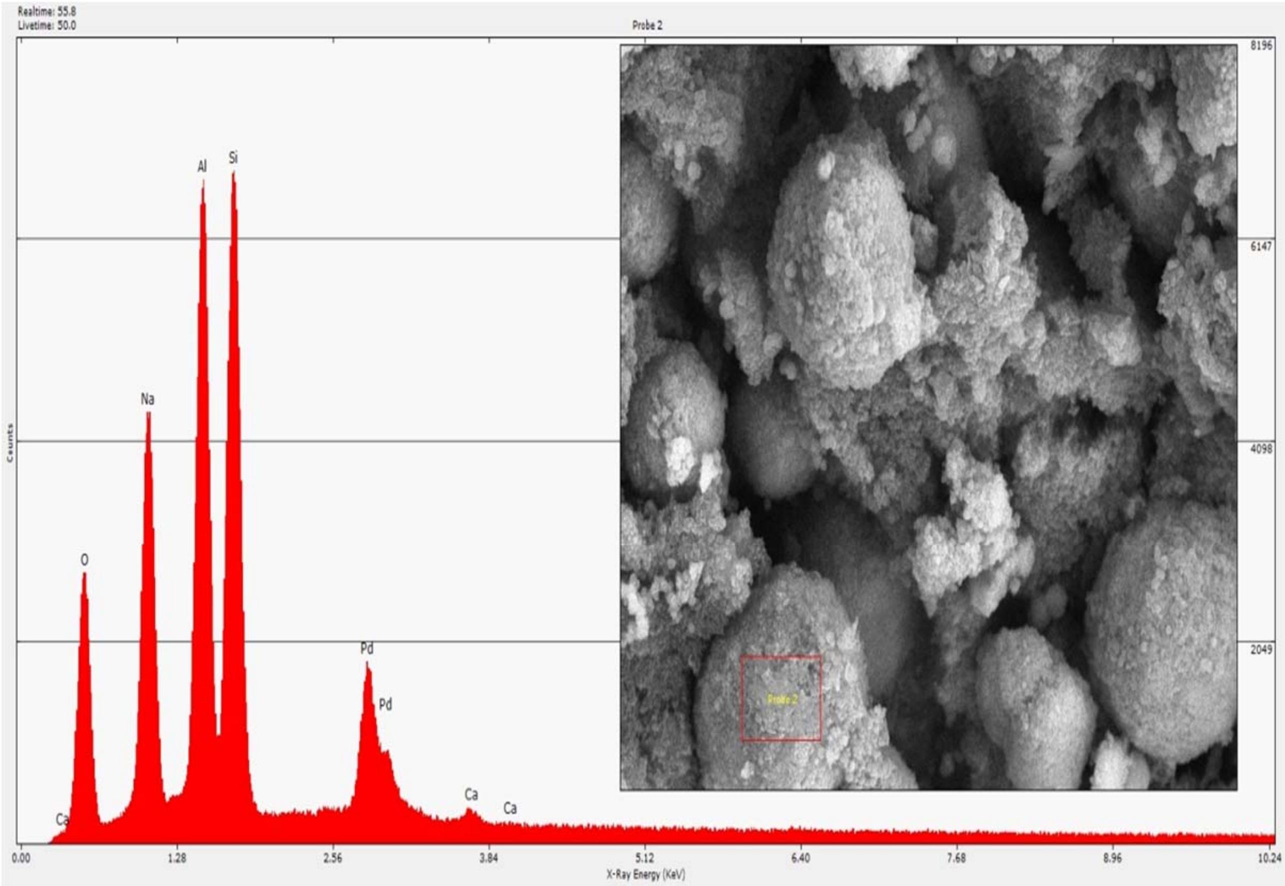


Figure 4.30. Sample Scraped and Washed from Lower Column Support after Test C (75°C) from SEM-EDS (upper place at 10 µm)



Quantitative Results for Probe 2
Analysis: Bulk Method: Standardless
Acquired 27-Sep-2011, 20.0 KeV @10 eV/channel

Element	Weight %	Std. Dev.	Atomic %
O	23.18	0.99	35.01
Na	19.61	0.89	20.61
Al	23.28	0.95	20.85
Si	24.87	0.97	21.40
Ca	0.19	0.07	0.12
Pd	8.87	0.81	2.01
Total	100.00		

Figure 4.31. Sample Scraped and Washed from Lower Column Support after Test C (75°C) from SEM-EDS (lower place at 10 µm)

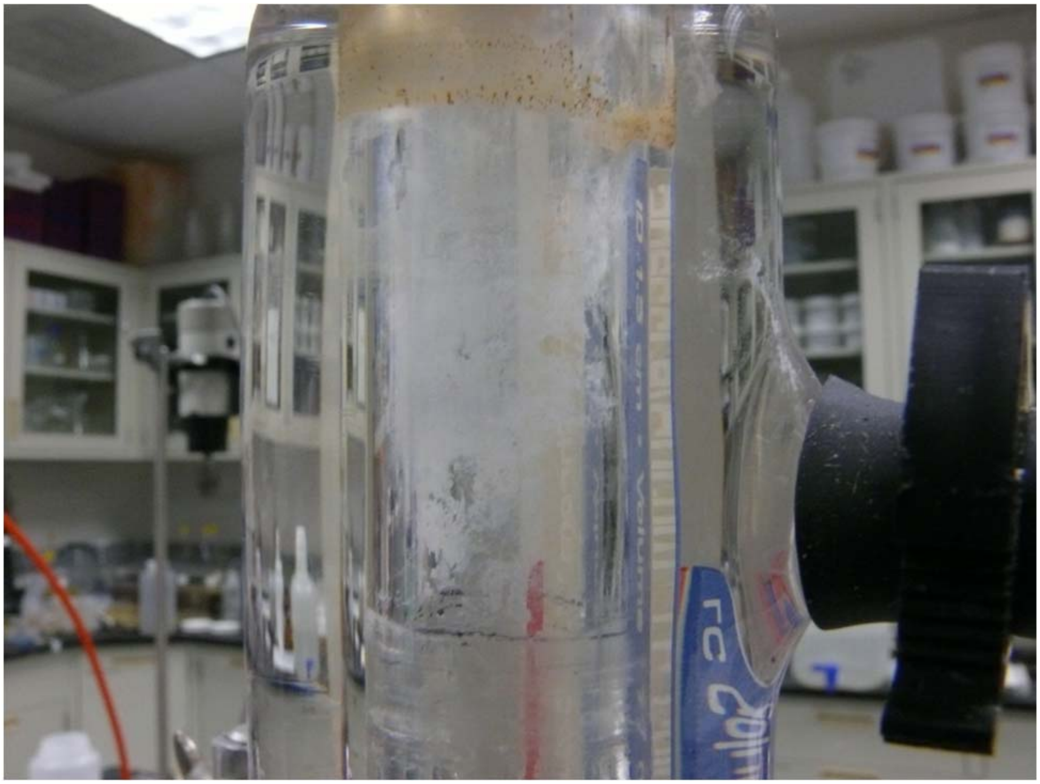


Figure 4.32. Debris Stuck to Column C after Testing at 75°C

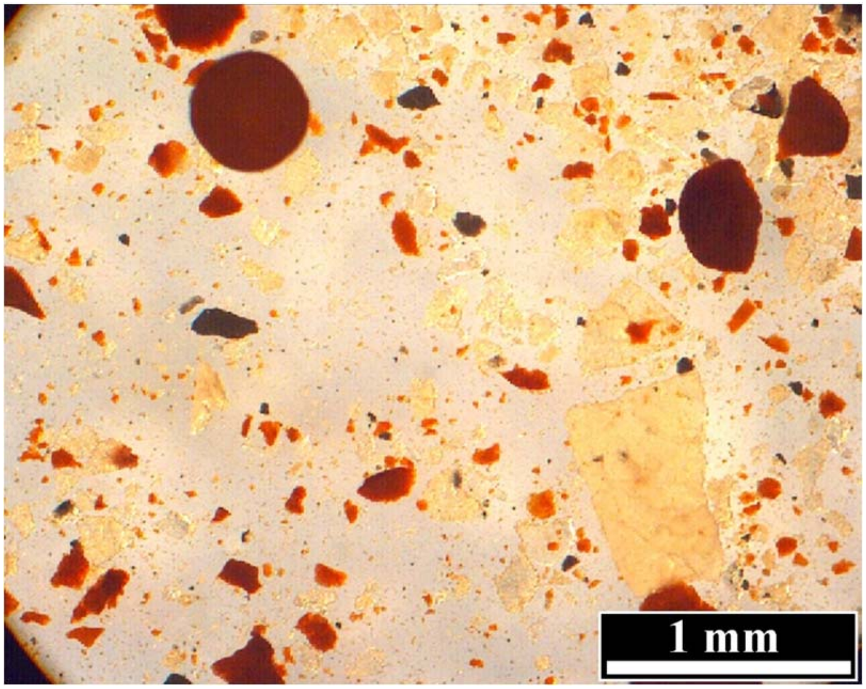


Figure 4.33. Sample Washed from the Lower Column Wall of Glass after Test C (75°C) from Optical Microscopy--70X

4.3 Effect of Aging Resin in an Acid Environment

Figure 4.34 portrays the results of the batch contact loading tests after the resin had been aged in 0.5 M HNO_3 for 70 days at various temperatures (25°C, 45°C, and 55°C). The non-aged samples were held in water for the 70 days instead of acid. Samples were taken after 0, 1, 4, 10, and 24 hours. The results show that the acid did not seem to affect the loading of the resin at 25°C. However, at 45°C, the kinetics of the resin loading were significantly reduced with a lower overall loading capacity (Figure 4.36). At 55°C the resin had completely disintegrated, as shown in Figure 4.35, and could not be loaded for comparison.

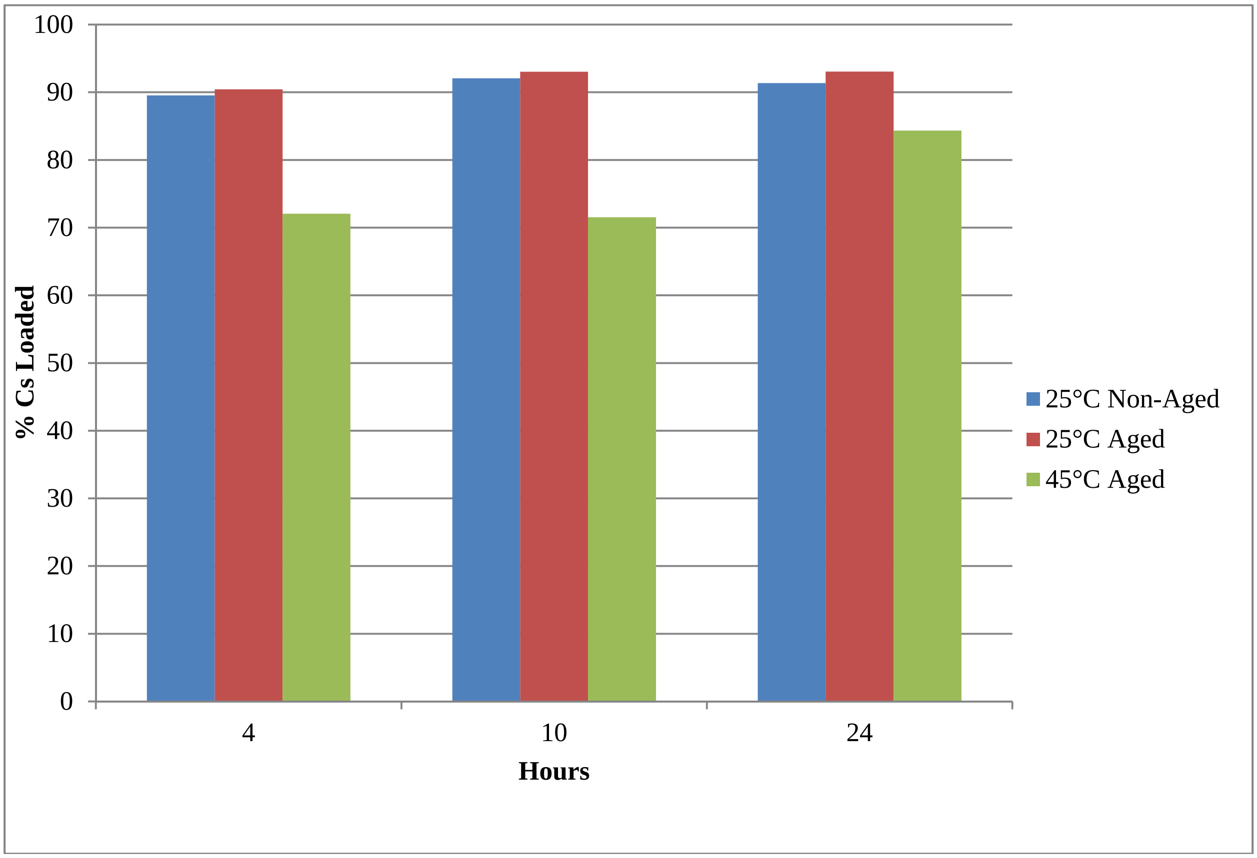


Figure 4.34. Resin Loading After 70 Days of Acid Aging

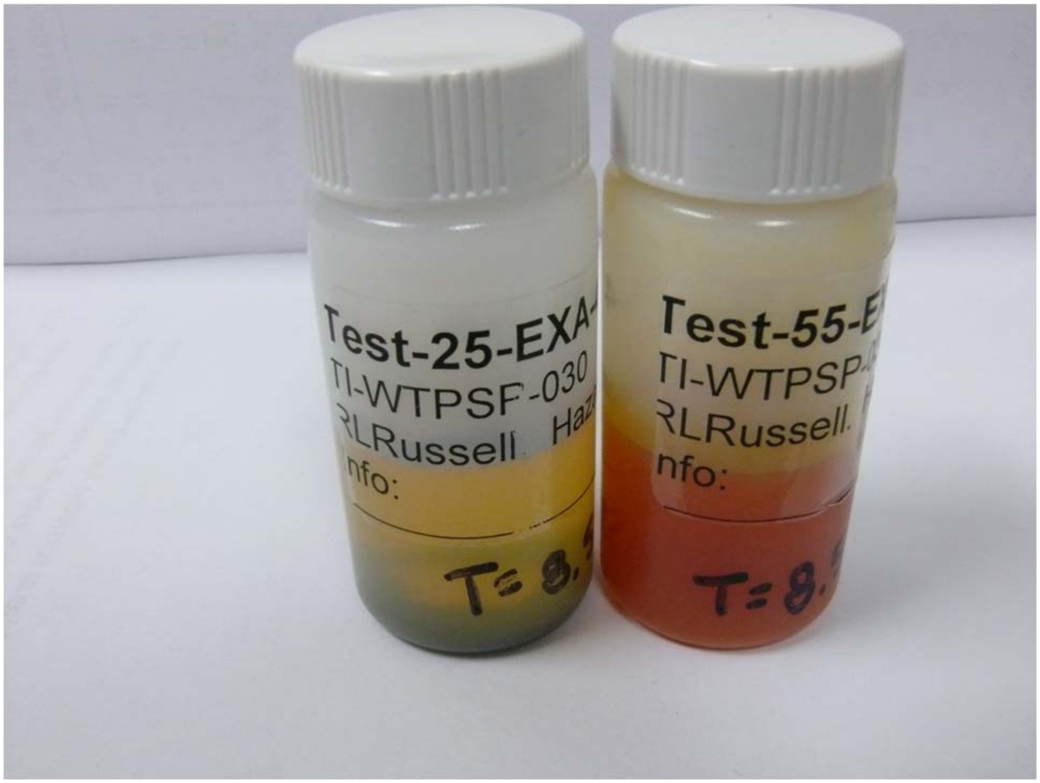


Figure 4.35. Resin Sample After Aging at 25°C for 70 Days Compared with 55°C Sample

SEM photos were taken of the aged resin at 25°C and 45°C and are shown in Figure 4.36. Not much difference was noticed in size of the resin spheres. However, the 45°C aged sample was darker in color indicating more oxidation, perhaps. Oxidation of the resin during the aging process could lead to reduced loading capacity.

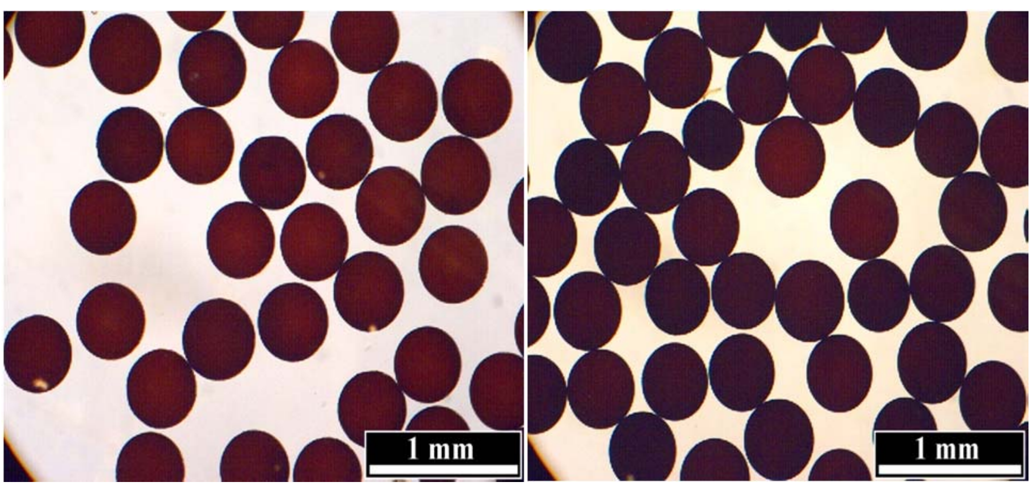


Figure 4.36. SEM of 25°C Acid Aged Resin (left) and 45°C Acid Aged Resin (right)

4.4 Effect on the Resin of Volatile Organics in the Feed

Figure 4.37 shows the results of the column ion exchange test performed with organics added to the feed. It is compared to Column A1 which was performed under the same conditions (45°C for 10 hours at 6 cm/min) and feed (5 M Na, 1.67 M OH, and 2.4E-05 M Cs) minus the organics. As can be seen, the presence of organics did not affect the loading capacity or kinetics of the loading at 45°C. This indicates that organics should not be a factor during ion exchange operation for the WTP at 45°C. However, increasing the temperature will decrease the overall resin loading capacity for the WTP.

About 8% of the added organics were removed by filtering through the KimWipe™ and a 0.1 µm filter after the feed was prepared. About 15% of the remaining organics were volatilized during heating from 25°C to 45°C. After heating and during column loading, no more organics were lost and the concentration remained essentially the same at about 44,000 mg/L TOC or about 5 wt%. The expected value in the WTP is <~4 wt% [(a)] indicating that the simulant was slightly higher in TOC than the expected feed. Table 4.1shows the measured values. The TIC values are most likely carbonates from the dissolved CO_2 present in the feed.

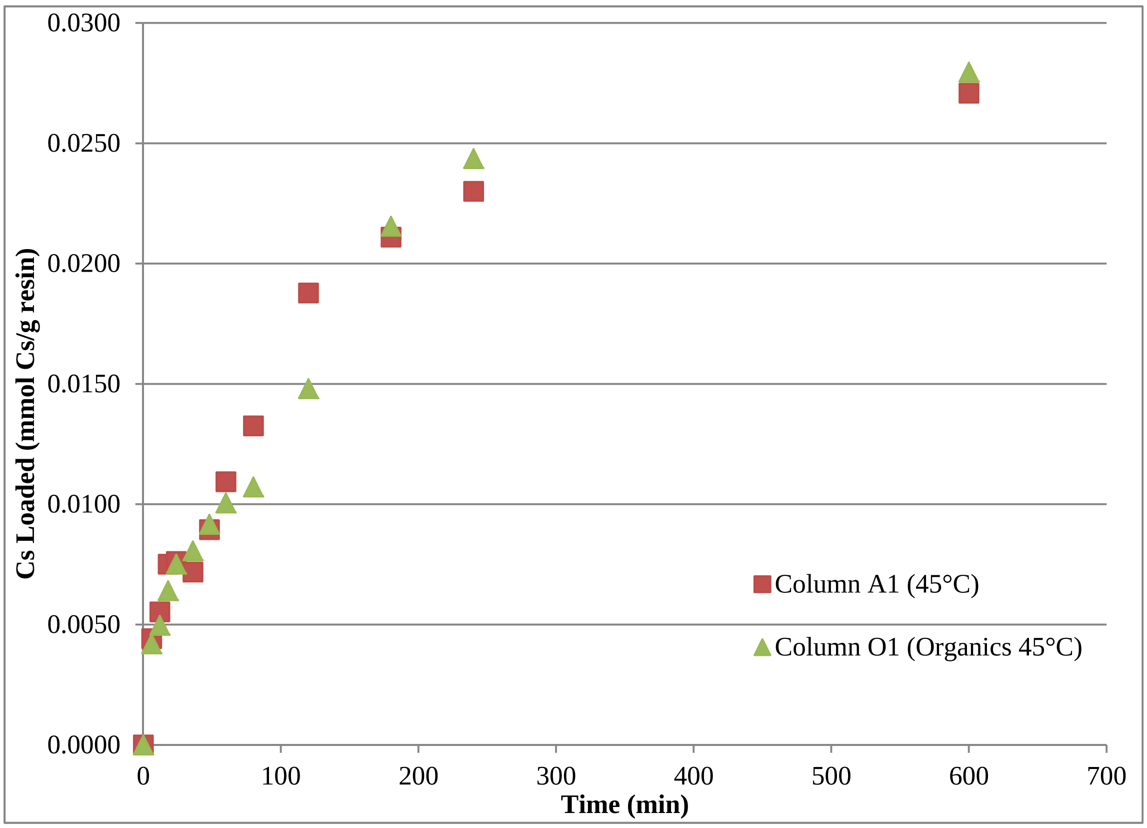


Figure 4.37. Results of the Organic Loading Test

(a) Received in e-mail from David Sherwood on March 14, 2012.

Table 4.1. Organic Levels in Feed

Sample ID	TOC (mg/L)	TIC (mg/L)
Feed Before Filtering	55,700	25.8
Feed After Filtering	51,350	63.4
Feed After Heating	43,800	69.0
Feed at End of Loading	44,900	70.0

5.0 Kinetics Model Results

Note: This section is for information only. The work described in this section uses a commercially available software program (VERSE-LC) in order to model the kinetic experiments. However, the software was not added to the approved software list under the QA program and thus, despite the technical validity of the work presented in this section, must be considered for information only.

The parametric tests conducted in the ion exchange columns described in Sections 3.7 and 4.1 demonstrated the effect of various conditions on column performance. In an attempt to understand how the parameter changes affected the kinetic behavior, the ion exchange experiments were modeled using the VErsatile Reaction-SEparation model for Liquid Chromatography applications (VERSE-LC). VERSE-LC is available for license from Purdue University, where it was originally developed (Berninger et al. 1991).

In the following sections, the application of VERSE-LC to the ion exchange experiments is presented. First, the model is briefly described. Second, the formulation of the problem of interest is elucidated, including the estimation of some of the input parameters that are required to perform physically realistic simulations. Third, the results of the modeling are presented. Finally, the results are summarized and possible improvements to the model are discussed.

5.1 Model Description

The VERSE-LC general equations are based on the general schematic given in Figure 5.1, where all of the general processes that may occur in a multiphase reaction-separation system are represented. The model has the capacity to include all the processes pictured in Figure 5.1, but in the ion exchange experiments the processes enclosed in the red dashed areas should be most important (i.e., film diffusion, intraparticle diffusion, and adsorption/desorption). The model was restricted to consider only these mechanisms when performing simulations. An exception is that cesium is in competition for adsorption on the resin with sodium and potassium, but these other species were not included for this kinetic study. The system is assumed to be a packed-bed column of length L and radius R with a mobile phase moving with the interstitial velocity u_o. The column is represented by a simple schematic in Figure 5.2. A series of dimensionless variables can be defined for space and time:

$$x = \frac{z}{L}; \quad \xi = \frac{r}{R}; \quad \tau = \frac{L}{u_o}; \quad \theta = \frac{t}{\tau},$$

where $\tau = L / u_o$ is the residence time, so defined to scale time. A series of dimensionless concentrations for the bulk (mobile), particle (pore), and solid phase concentrations are defined, respectively, as

$$c_{b_i} = \frac{C_{b_i}}{C_{e_i}}; \quad c_{p_i} = \frac{C_{p_i}}{C_{e_i}}; \quad \overline{c}_{p_i} = \frac{\overline{C}_{p_i}}{\overline{C}_{T_i}},$$

where C_{ei} is the maximum possible inlet concentration for species i and $\overline{C}_{T_i}$ is the maximum solute capacity for species i. The subscripts b and p refer to concentrations in the bulk (mobile) phase and particle (pore) phase. The overline indicates a solid phase concentration, whereas no overline implies liquid phase.

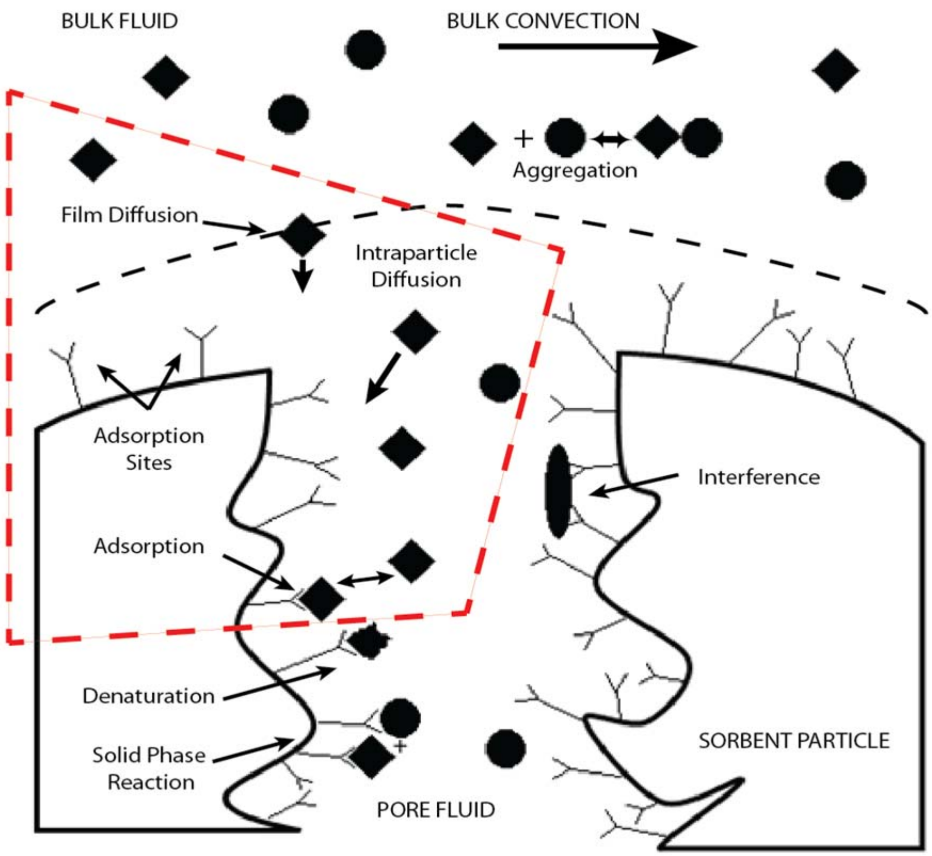


Figure 5.1. General Schematic of the VERSE-LC Equation System. The physical processes enclosed by the red dashed areas are dominant in the ion exchange system and will be the only processes considered.

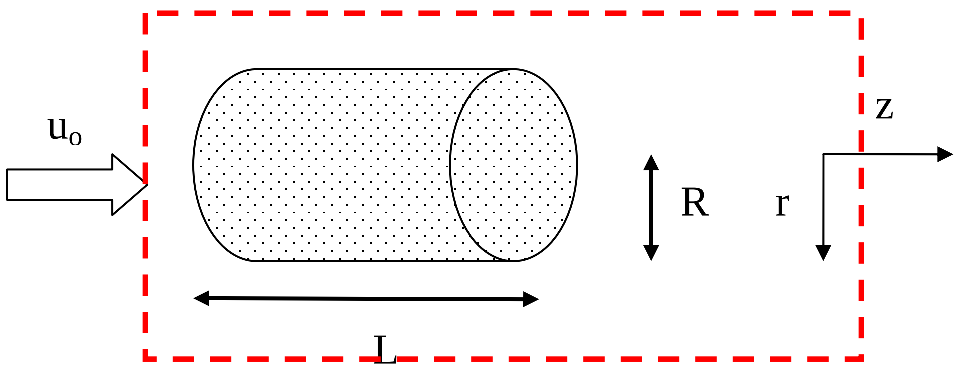


Figure 5.2. Schematic of the Model Column and Relevant Physical Dimensions

With these dimensionless variables, the general equations for each phase are written as follows:

Mobile phase

$$\frac{\partial c_{b_i}}{\partial \theta} = \frac{1}{Pe_{b_i}} \frac{\partial^2 c_{b_i}}{\partial x^2} - \frac{\partial c_{b_i}}{\partial x} + Y_{b_i} - N_{f_i} \left(c_{b_i} - c_{p_i} \big|_{\xi=1} \right), \tag{5.1}$$

where Pe_b is the Peclet number in the bulk phase, Y_b is the generation of species by reaction in the bulk phase, and N_f is dimensionless film mass transfer number based on the feed. These are defined more specifically below. Equation (5.1.) is subject to the boundary conditions

$$x = 0; \quad \frac{\partial c_{b_i}}{\partial x} = Pe_{b_i} \left(c_{b_i} - c_{f_i}(\theta) \right), \tag{5.2}$$

$$x = 1; \quad \frac{\partial c_{b_i}}{\partial x} = 0, \tag{5.3}$$

$$\theta = 0; \quad c_{b_i} = c_{b_i}(0, x); \tag{5.4}$$

Pore phase

$$Ke_i \left[\varepsilon_p \frac{\partial c_{p_i}}{\partial \theta} - \varepsilon_p Y_{p_i} \right] + \left(1 - \varepsilon_p\right) \left(\frac{\bar{C}_{T_i}}{C_{e_i}} \right) Y_{l_i} = N_{p_i} \frac{1}{\xi^2} \frac{\partial}{\partial \xi} \left[\xi^2 \frac{\partial c_{p_i}}{\partial \xi} \right], \tag{5.5}$$

where Ke is a size exclusion factor and ε_p is the intraparticle void fraction. Equation (5.5) is subject to the boundary conditions

$$\xi = 0; \quad \frac{\partial c_{p_i}}{\partial \xi} = 0, \tag{5.6}$$

$$\xi = 1; \quad \frac{\partial c_{p_i}}{\partial \xi} = Bi_i \left(c_{b_i} - c_{p_i} \right), \tag{5.7}$$

$$\theta = 0; \quad c_{p_i} = c_{p_i}(0, \xi). \tag{5.8}$$

Recall as previously discussed that the subscript i refers to species i, and these equations can be written for multiple-component systems. For simplicity, the i will be dropped in subsequent equations since this is a single-component system (only the kinetics of cesium will be considered). The subscripts b, p, and f refer to the bulk (mobile) phase, particle (pore) phase, and feed stream, respectively. The variable Y represents generation by reaction, which needs to be specified but in general can occur in the bulk phase, particle phase, or by an adsorption/desorption process (subscript l). The dimensionless numbers Pe_b, Bi, N_f, and N_p are defined as follows:

$$Pe_b = \frac{u_o L}{E_b}; \quad Bi = \frac{k_f R}{E_p}; \quad N_f = 3\left(\frac{L}{R}\right)\frac{(1-\varepsilon_b)k_f}{\varepsilon_b u_o}; \quad N_p = \frac{L}{R}\left(\frac{E_p}{u_o R}\right),$$

where E_b is the axial dispersion coefficient, E_p is the effective intraparticle diffusivity, ε_b is the interparticle void fraction, and k_f is the film mass transfer coefficient.

Given the requisite information, Equations (5.1) through (5.8) can be solved by numerical methods. There are five basic assumptions required for the solution to be representative of the physical system it is modeling:

1. The column packing is homogeneous (spherical particles, same particle and pore size);
2. The column is packed homogenously, resulting in a uniform flow distribution;
3. The system is isothermal;
4. Concentration gradients are in the radial direction r and in the angular directions inside a particle;
5. Mass transfer coefficients are constant and do not depend on other mechanisms.

Using these assumptions, the equations are discretized and solved using the method of orthogonal collocation on finite elements. This is a robust method, even for stiff problems since the discretization is flexible enough to handle shallow or steep concentration fronts. The method and solution methods are described in more detail in Yu and Wang (1989) and Berninger et al. (1991).

5.2 Formulating the Problem

The ion exchange experiments were performed slightly differently than the VERSE-LC model system is setup, so some adjustments were needed to match the simulation with the physical situation. The base VERSE-LC model system, shown in Figure 5.3, is compared to the experimental system. The major differences are that recycle is not assumed in the VERSE-LC model and there are continuous stirred tank reactors (CSTRs) on the inlet and outlet sides of the column. VERSE-LC does have a recycle mode option but there are two complications when using this mode, namely

1. The initial concentration applies to the entire column. This cannot be altered in the software.[a] If the actual cesium feed concentration were to be input at t = 0, there is no reaction/adsorption because mathematically the system is already at equilibrium.
2. The CSTRs are assumed to be at the same equilibrium concentration as the column. Thus, they cannot be specified to reflect the physical reality of a feed vessel inputting a stream that has a much higher cesium concentration than the column itself.

These complications are artifacts of the original scope of VERSE-LC simulations, which were primarily for liquid chromatography experiments.

(a) Current version of VERSE-LC is 2011-07-12-183156.

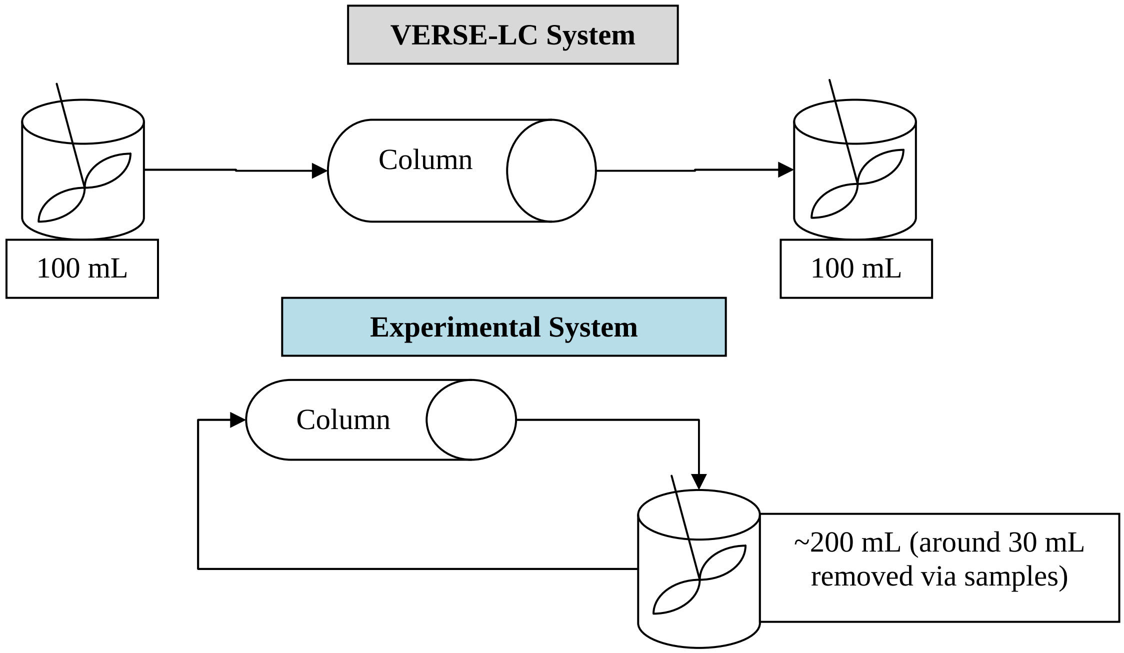


Figure 5.3. Comparison of VERSE-LC System with Experimental System Used

To circumvent these complications, the simulation was started without recycle in order to “flood” the column and CSTRs with a high flow rate (1000 mL/min). The objective of the “flooding” was to reach the target initial concentration of Cs rapidly without appreciably reducing the capacity of the column. This was accomplished in one minute or less. The flow rate and concentration were then step-changed to the desired initial values and the recycle was initiated a microsecond after the step-change. The limitation of this approach is that there is a small amount of Cs adsorbed during the high flow rate period, which will affect the kinetic parameter estimation. It is not clear from the software where the recycle stream returns in the model system; it is assumed to be a total recycle as in the experimental system.

Because this is a system where the feed concentration is changing in response to adsorption in the column, the simulations cannot use an isotherm to accurately model the experiments. Isotherms have been studied in detail for Cs ion exchange using this resin, including modeling using VERSE-LC, in particular at Savannah River National Laboratory (Hamm et al. 2002; King et al. 2004; Hardy et al. 2004; Smith 2007; and Smith et al. 2009). In this case, the ion exchange is inherently a non-equilibrium separation process. The most common kinetic (i.e., non-equilibrium) model is a Langmuir model of the form

$$Y_l = \frac{\tau}{\overline{C}_T}\left[\ell_+ C_p \overline{C}_T \left(1 - \sum_{k=1}^{N} \frac{\overline{C}_{p.k}}{\overline{C}_{T,k}}\right) - \ell_- \overline{C}_p\right], \tag{5.9}$$

where ℓ_+ and ℓ_- are the adsorption and desorption reaction rate constants, respectively. Recall that the overbar refers to the solid phase concentrations and that the subscript i was removed because this is a single component system (Cs kinetics only). The summation term is shown for generality, but in the single component case of this study, $N = 1$ and no summation is required.

The accuracy of the non-equilibrium Langmuir kinetic equation will depend heavily on an accurate estimate of C_T, which is the maximum solute capacity of the resin for Cs. The capacity is assumed to be a property of the resin alone and not affected by temperature, composition, or other feed conditions. There are a few sources from which C_T can be evaluated. One method is to use available information from King et al. (2004). The capacity of the SRF resin is quoted as 0.5 mmol Cs/g dry resin. Thus, to convert into units of mol/L:

$$\bar{C}_T \approx \left(\frac{0.5\text{ mmol}}{\text{g dry resin}}\right)\left(\frac{0.40\text{ g dry resin}}{\text{mL}}\right) = 0.2\text{ mol L}^{-1}$$

where the dry bed density is based on estimates of bed volume for the ion exchange columns used in this work. There is also an extensive set of Langmuir isotherm data already available [see, for example, Smith (2007)]. The single component Langmuir isotherm is typically written as

$$\bar{C}_p = \frac{aC_p}{1+bC_p} \tag{5.10}$$

where a and b are isotherm constants. In the case of fast adsorption/desorption, the non-equilibrium and isotherm Langmuir models are related via the expressions

$$b = \frac{\ell_+}{\ell_-} \tag{5.11}$$

and

$$a = \frac{\ell_+}{\ell_-}\bar{C}_T\,. \tag{5.12}$$

Thus, upon a simple rearrangement

$$\bar{C}_T = \frac{a}{b}, \tag{5.13}$$

and the available isotherm data give an average a/b of 0.17. The same isotherm data also indicate that $\ell_+ \sim 10^3\,\ell_-$. The C_T value of 0.17 was used as a reasonable starting point for the simulations.

The estimation of physical parameters was also challenging, in particular the viscosity of the solution and the diffusion coefficient of Cs. The viscosity is a function of the temperature and composition, both of which were varied during these experiments. The diffusion coefficient depends on the presence of counter ions, temperature, and the solution viscosity. Both of these parameters were estimated by constructing them from mass (viscosity) or molar (diffusion coefficient) averages of simpler data sets.

The viscosity was calculated using the equation

$$\mu_{agg} = \left(\frac{\mu_{T,NaNO_3}}{\mu_{25,NaNO_3}}\right)\sum_{j=1}^{3} x_j \mu_{Na-j} \tag{5.14}$$

where μ_{agg} is the aggregate viscosity of the mixture, $\mu_{T,NaNO3}$ and $\mu_{25,NaNO3}$ are experimentally determined viscosities for an aqueous $NaNO_3$ system (Abdulagatov and Azizov 2005), x_j is the mass fraction of compound j, and $\mu_{Na\text{-}j}$ is the viscosity of an aqueous solution of Na^+-j at the experimental weight fraction and 25°C. In this case, j represents the three anions NO_3^-, OH^-, and Cl^-. The effect of aluminum is ignored. The viscosity of each sodium compound was correlated with weight fraction using data from Perry's Chemical Engineering Handbook (7th edition) using cubic polynomials. The temperature dependence of the $NaNO_3$ compound is assumed to be representative of the composite temperature dependence.

The calculation of the diffusion coefficient depends on binary interactions between ions. At infinite dilution,

$$D_{\pm}^{\infty} = \left(\frac{RT}{F^2}\right)\left[\frac{\dfrac{1}{z_+}+\dfrac{1}{z_-}}{\dfrac{1}{\lambda_+^o}+\dfrac{1}{\lambda_-^o}}\right], \tag{5.15}$$

where R is the ideal gas constant, T is the absolute temperature, F is Faraday's constant, z_+ and z_- are the valences of the binary ion pair, and λ_+^o and λ_-^o are the limiting conductivity for the ion pair. The limiting conductivity is calculated via

$$\ln\left[\lambda^o(T)\eta(T)\right] = A + \frac{B}{T} \tag{5.16}$$

where $\eta(T)$ is the viscosity of pure water and A and B are constants (available from sources such as the CRC Handbook of Chemistry and Physics). Assuming that the Stokes-Einstein relationship is valid for these scenarios, then the diffusion coefficient will be reduced by a ratio of viscosities, giving the final relationship for the overall Cs diffusion coefficient:

$$\langle D_{Cs}\rangle = \frac{\eta(T)}{\mu_{agg}}\sum_i X_i D_{Cs-i}^{\infty}\ . \tag{5.17}$$

The viscosity is already described by Equation (5.14). The summation includes all the relevant binary pairs in the solution fed to the ion exchange column, with X_i being the mole fraction of the Cs-i pair and $D_{Cs\text{-}i}^{\infty}$ the binary diffusion coefficient as calculated by Equation (5.15). The pore diffusivity can be estimated as either

$$D_p = \frac{\langle D_{Cs}\rangle}{\psi} \quad \text{or} \quad D_p = \frac{\varepsilon_p}{\left(2-\varepsilon_p\right)^2}\langle D_{Cs}\rangle\ .$$

The first approach that was taken in these simulations was with the tortuosity $\psi = 3$. Note that the values of D_p are very similar if the second approach is used with the known value of ε_p.

Other physical parameters not mentioned specifically in this section were either measured during the experimentation or values were used based on previous work with the same resin (e.g., King et al. 2004; Hardy et al. 2004; Smith 2007).

5.3 Results and Discussion

The results discussed in this section were obtained in the following manner. Simulations in VERSE-LC were run using guesses for ℓ_+ and ℓ_- with $C_T = 0.17$. The resulting concentration time series were compared to experimental results of the ion exchange work at discrete points in time. Iterations were conducted on this process in an effort to minimize the square of the residuals. Due to limitations of the VERSE-LC software interface, this was a manually iterative process. Thus, though some effort was expended to minimize the error between the simulation and the data, the result is not a true minimum. Optimization of the method was not performed in the interest of computation time.

An example model fit is shown in Figure 5.4. The fit is in good agreement with the data and satisfies the general heuristic that ℓ_+ is approximately 10^3 times greater than ℓ_-, as has been observed in past work (Smith 2007). A second example is shown in Figure 5.5. Again, the fit is in good agreement with the data and ℓ_+ is approximately 10^3 times greater than ℓ_-. This fit is shown to demonstrate that the simulation can approximate the experimental data when the adsorption and desorption rates are faster than the ones in Figure 5.4. These two figures are representative of the results obtained from the manual optimization method used to compare the simulations with the data.

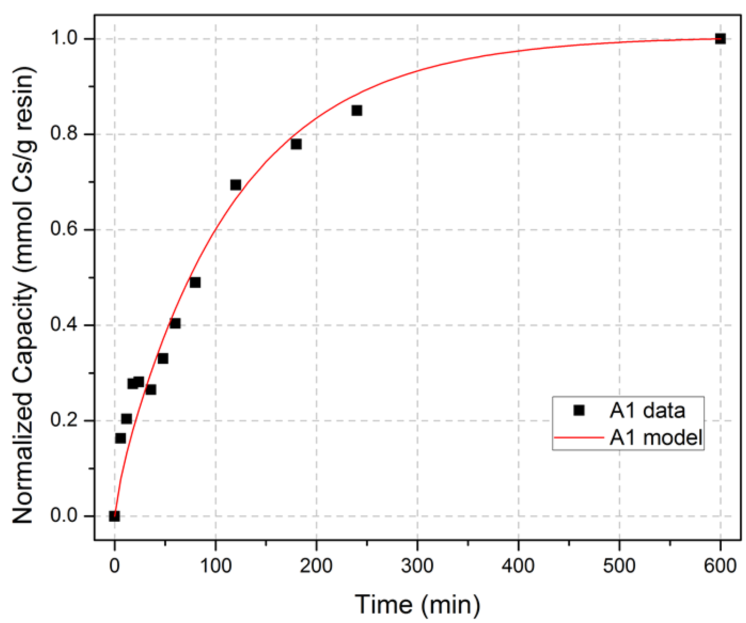


Figure 5.4. Fit of the VERSE-LC Simulation to the Column A1 Experimental Data. The final model had the following values: $\ell_+ = 25$ L mol^{-1} s^{-1}, $\ell_- = 2.0 \times 10^{-3}$ s^{-1}, with a root mean squared error of 0.042.

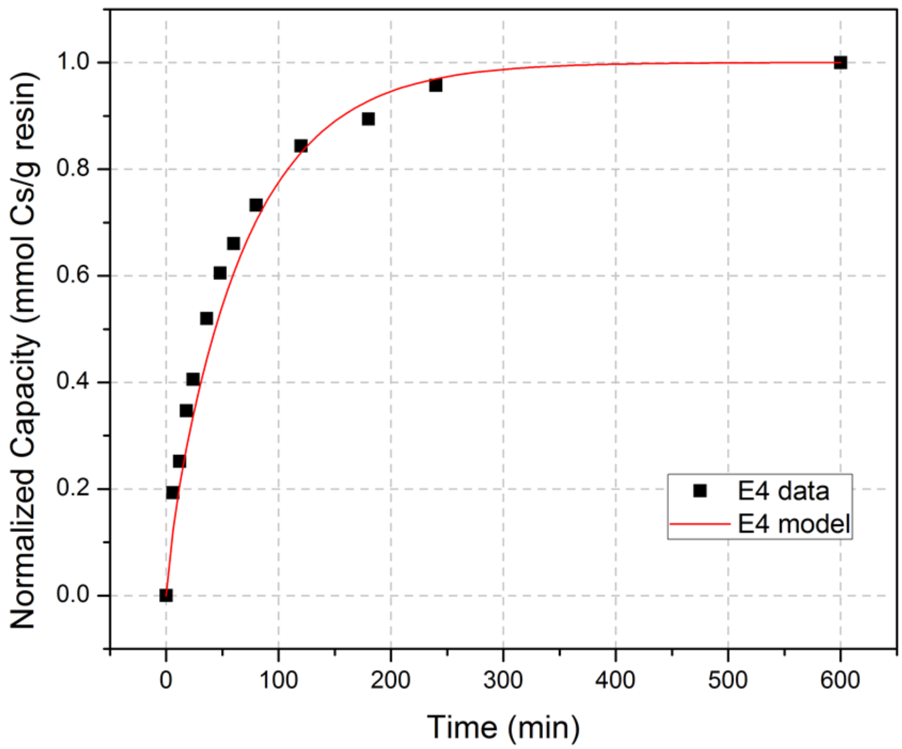


Figure 5.5. Fit of the VERSE-LC Simulation to the Column E4 Experimental Data. The final model had the following values: $\ell_+ = 60$ L mol^{-1} s^{-1}, $\ell_- = 7.5 \times 10^{-3}$ s^{-1}, with a root mean squared error of 0.025.

The approach for the remainder of this section is to look at cross-sections of the experimental data in an attempt to determine if there are any discernible trends in adsorption and desorption behavior with changes in a given parameter. Note that some of the parameter changes are taken into account directly in the model; for instance, changes in mobile phase flow rate are handled via correlations for the axial dispersion and film diffusion coefficients.

First, simulation results for different sodium concentrations in the feed solution are given in Table 5.1. In each case, the ratio of the adsorption and desorption rate constants are calculated from experiments conducted as part of the same data set. The sodium molarities are given in parentheses. The adsorption rate constant does not appear to change if sodium is present at 5 or 8 M, but the 8 M sodium has a lower adsorption rate than 2 M sodium. This is consistent with the expectation that sodium competes with Cs for adsorption sites in the resin pores. The desorption rate constant is larger when the sodium molarity is higher, suggesting a similar competition effect. The VERSE-LC simulations indicate that running the ion exchange columns at low sodium concentration is optimal for the best kinetic performance. However, above a certain Na concentration (above 2 M but 5 M or less), the adsorption kinetics are not changed much. Since adsorption dominates the desorption process, above this point there will be little difference in column performance (as observed experimentally). Furthermore, the model does not account for the interaction of sodium with the column. Inclusion of sodium in a future model would help clarify the role sodium plays in adsorption/desorption kinetics of cesium.

Next, the effect of temperature is considered. Table 5.2 presents the results of experiments at 25, 45, and 50°C. The results at 50°C give an idea of the variability between simulation results based on three experiments conducted at the same conditions. Considering that each experiment is also subject to some random error, the spread in the simulation results is quite reasonable. The temperature data did not indicate a strong trend of adsorption or desorption rate with temperature. In fact, if the discontinuity in the Column A1 data is discarded and only the initial data are modeled, the values that are given in brackets were found to be the best fit to the data. The dimensionless number ($C_f \ell_+ / \ell_-$ --- a dimensionless adsorption number) in the fourth column is essentially invariant to temperature; thus, no discernible trend with temperature was observed.

Table 5.1. Effect of Sodium Concentration on Adsorption and Desorption Rate Constants

Ratio of Experiments (Na^+ M)	ℓ_+ Ratio	ℓ_- Ratio	Velocity (cm/min)
A2 (8) / A1 (5)	1.00	2.50	6
B4 (8) / B3 (2)	0.35	1.67	4
C4 (8) / C2 (2)	0.29	1.67	8
E2 (8) / E1 (5)	1.00	2.25	6
E4 (8) / E1 (5)	0.80	1.88	6

Table 5.2. Effect of Temperature on Adsorption and Desorption Rate Constants

Experiment (T in °C)	ℓ_+ (L mol^{-1} s^{-1})	ℓ_- (s^{-1})	($C_f \ell_+$) / ℓ_-	Notes
D1 (25)	80	3.75×10^{-3}	0.58	All experiments at: velocity of 6 cm/min, Na^+ = 5 M, OH^- = 1.67 M, initial Cs = 2.4×10^5 M
A1 (45)	25 [*55*]	2.00×10^{-3} [2.00×10^{-3}]	0.33 [*0.66*]	
B1 (50)	110	4.50×10^{-3}	0.71	
C1 (50)	50	3.00×10^{-3}	0.46	
E1 (50)	75	4.00×10^{-3}	0.61	
Average (50)	**78**	$\mathbf{3.83 \times 10^{-3}}$	**0.59**	

The results of the VERSE-LC simulations for subsets where the flow rate was varied between experiments are presented in Table 5.3. The adsorption rate constant goes up with increases in flow rate. Likewise, the desorption rate constant also increases, particularly at higher Na concentrations. This is surprising because it suggests that the Cs adsorption kinetics depend on the flow rate of the mobile phase. The flow rate is expected to affect mass transport mechanisms, such as is already captured in the film diffusion coefficient and axial dispersion coefficient. However, this effect alone is not sufficient to capture the difference in the data that was observed in the ion exchange columns experimentally. This is demonstrated graphically in Figure 5.6. The data from Column C2 experiment and the simulation fit to it are shown. Then the constants from the Column C2 fit were used to model the Column C3 experiment (which was conducted at half the flow rate of Column C2), changing only the flow rate to the Column C3 value. The change in the simulation result is very small compared to the change in the data. This result does not match what is expected based on current understanding of the ion exchange system and should be investigated further.

Table 5.3. Effect of Flow Rate on Adsorption and Desorption Rate Constants

Ratio of Experiments (velocity in cm/min)	ℓ_+ Ratio	ℓ_- Ratio	Na^+ (M)
A2 (6) / A3 (4)	0.76	1.32	8
B2 (8) / B3 (4)	1.50	1.00	2
C2 (8) / C3 (4)	3.43	1.50	2
E2 (6) / E3 (4)	3.00	2.25	8

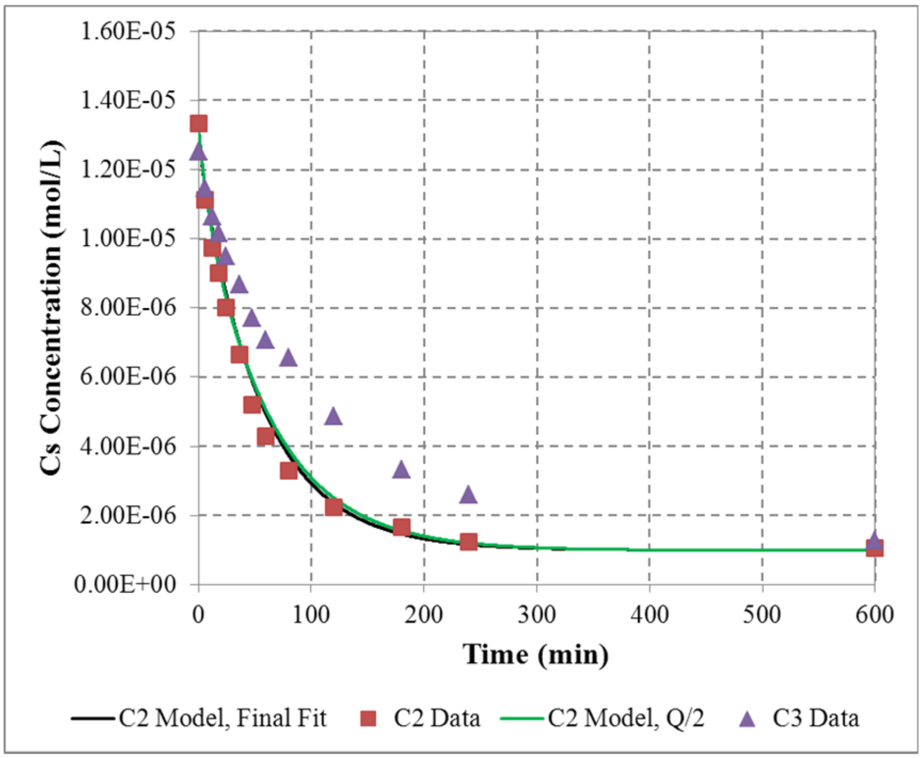


Figure 5.6. Comparison of Experimental Data with Simulation Results When Only the Flow Rate is Changed in the Column C3 Simulation

It is possible that some mechanism that is outside of the processes captured by the VERSE-LC model is having some effect in the physical experiments. If VERSE-LC does not contain the proper physics, then the difference will show up in the adsorption and desorption rate constant since it is not being captured correctly by the simulation. A couple potential causes can be proposed. One is that the column is not packed uniformly and is subject to experiencing channeling in the packed bed. This will be magnified at lower flow rates where the fluid will choose the path of least resistance and thus not be exposed to all the active sites in the resin. As the flow rate increases, it becomes sufficient to access parts of the porous substructure that was previously not accessible and the effective adsorption and desorption rates increase. Another possibility is that there is an intraparticle convection that enhances the diffusivity of Cs at higher flow rates, thereby bringing more Cs in proximity to adsorption sites. This would also appear to be a higher adsorption rate constant. The first cause would be more likely given the dimensions of the test column and the flow rates used.

The effect of OH^- concentration on rate constants is shown in Table 5.4. The effect is difficult to separate from other variables, since OH^- dependence was not a variable that was intentionally examined during the testing. Na^+ concentration also necessarily increases with OH^- concentration so this complicates the analysis. However, if the adsorption and desorption rate constants are adjusted on the basis of 4 cm/min and 8 M Na^+ concentration, then the adjusted constants (in particular the adsorption rate constant) show almost no change with OH^- concentration above 1 M.

Table 5.4. Effect of OH^- Concentration on Adsorption and Desorption Rate Constants

Experiment (OH^- M)	ℓ_+ (L mol^{-1} s^{-1})	ℓ_- (s^{-1})	Na^+ (M)	Velocity (cm/min)	Adjusted ℓ_+	Adjusted ℓ_-
B2 (0.5)	150	4.50×10^{-3}	2	8	100	4.50×10^{-3}
C2 (1.0)	120	3.00×10^{-3}	2	8	35	2.00×10^{-3}
A1 (1.67)	25	2.00×10^{-3}	5	6	33	1.52×10^{-3}
A2 (2.0)	25	5.00×10^{-3}	8	6	33	3.80×10^{-3}
B4 (4.0)	35	7.50×10^{-3}	8	4	35	7.50×10^{-3}

Each experimental set included a repeat experiment after some experiments were conducted in between. The simulation results from the repeat sets are shown in Table 5.5. On average, the adsorption rate does not appear to be affected by the amount of elapsed processing time a column experiences. However, the desorption rate was larger for every repeat experiment, suggesting that elapsed processing time improves the desorption kinetics. This is consistent with what is known about SRF resin, since it degrades over time and is affected by processing cycles. Note that due to increased desorption kinetics, a column will reach steady-state faster the more times in has been used, albeit at a lower Cs capacity.

Table 5.5. Effect of Column Processing Time/Cycling on Adsorption and Desorption Rate Constants

Ratio of Experiments	ℓ_+ Ratio	ℓ_- Ratio	Notes
A5 / A1	1.60	2.50	All experiments at: velocity of 6 cm/min, Na^+ = 5 M, OH^- = 1.67 M, initial Cs = 2.4×10^5 M
B5 / B1	0.50	2.44	
C5 / C1	1.00	6.67	
E5 / E1	1.00	1.63	
Average	**1.03**	**3.31**	

5.4 Conclusions

The VERSE-LC simulation tool provided insight regarding the kinetic behavior of the ion exchange experiments described in this report. The final simulation results [the parameters that gave the best fit as measured by minimizing the RMSE (root mean square error)] are shown in Table 5.6. In general, the following conclusions can be drawn:

- Increased sodium content (above 2 M) may slow down the adsorption/desorption as sodium competes with cesium for resin actives sites. However, simulations indicated that 5 and 8 M sodium have very similar adsorption/desorption rates.
- Temperature did not strongly impact adsorption/desorption rate constants.
- Contrary to expectation, the flow rate had a strong effect on the adsorption/desorption rate constants that is outside usual mass transfer mechanisms. This was speculated to arise from channeling in the column, convectively-enhanced pore diffusion of cesium, or some other unknown mechanism that is not currently a part of the model.
- The hydroxide concentration has little or no effect on adsorption and desorption above a concentration of 1 M.
- As a column is used over time, it will reach steady-state faster during each subsequent processing cycle. The steady-state will have a lower cesium capacity.

Table 5.6. Final Simulation Results for All Experiments Modeled Using VERSE-LC

Experiment	ℓ_+ (L mol^{-1} s^{-1})	ℓ_- (s^{-1})	Sum of square of residuals ($\Sigma\Delta^2$)	Number of data points (N)	Root mean squared error (RMSE)
D1	80	3.75×10^{-3}	2.15×10^{-2}	13	4.06×10^{-2}
A1	25	2.00×10^{-3}	2.28×10^{-2}	13	4.19×10^{-2}
A2	25	5.00×10^{-3}	8.39×10^{-3}	13	2.54×10^{-2}
A3	33	3.80×10^{-3}	1.85×10^{-2}	13	3.77×10^{-2}
A4	25	7.00×10^{-3}	2.93×10^{-2}	13	4.75×10^{-2}
A4B	0.15	8.00×10^{-5}	4.53×10^{-1}	12	1.94×10^{-1}
A5	40	5.00×10^{-3}	6.23×10^{-2}	15	6.44×10^{-2}
E1	75	4.00×10^{-3}	2.16×10^{-2}	13	4.07×10^{-2}
E2	75	9.00×10^{-3}	6.67×10^{-3}	13	2.27×10^{-2}
E3	25	4.00×10^{-3}	6.08×10^{-3}	13	2.16×10^{-2}
E4	60	7.50×10^{-3}	8.33×10^{-3}	13	2.53×10^{-2}
E4B	1	5.00×10^{-3}	5.22×10^{-2}	12	6.59×10^{-2}
E5	75	6.50×10^{-3}	3.06×10^{-2}	15	4.52×10^{-2}
B1	110	4.50×10^{-3}	3.38×10^{-2}	15	4.75×10^{-2}
B2	150	4.50×10^{-3}	6.25×10^{-2}	15	6.45×10^{-2}
B3	100	4.50×10^{-3}	7.73×10^{-3}	15	2.27×10^{-2}
B4	35	7.50×10^{-3}	2.16×10^{-3}	13	1.29×10^{-2}
B4B	0.25	5.00×10^{-4}	1.10×10^{-1}	10	1.05×10^{-1}
B5	55	1.10×10^{-2}	1.10×10^{-2}	13	2.91×10^{-2}
C1	50	3.00×10^{-3}	6.36×10^{-3}	15	2.06×10^{-2}
C2	120	3.00×10^{-3}	1.38×10^{-2}	15	3.03×10^{-2}
C3	35	2.00×10^{-3}	1.05×10^{-2}	15	2.64×10^{-2}
C4	35	5.00×10^{-3}	1.46×10^{-2}	13	3.35×10^{-2}
C4B	--	--	--	9	--
C5	50	2.00×10^{-2}	3.23×10^{-3}	13	1.58×10^{-2}

There were some limitations to using the VERSE-LC model that could be mitigated with additional time. First, the interface of the software was not conducive to a more automated minimization routine. This could be automated to find a minimum using any standard optimization routine, but would have to involve a second software platform. Second, the accuracy of the results could also be improved with better input data, in particular a good estimate of the maximum solute capacity for cesium and accurate measurement of the physical properties of the solution (viscosity and diffusion coefficients in particular). Third, a more complex model could be built that incorporates some of the ignored species such as Rb^+, K^+, and Na^+ that compete with Cs^+ for adsorption sites on the resin.

6.0 Conclusions

Kinetics tests were performed with simulants with varying Na concentrations, OH concentrations, Na/Cs ratios, Na/OH ratios, and linear velocities using SRF resin in an ion exchange column. It was found that Cs loading kinetics were not significantly impacted by the sodium concentration, OH concentration, Na/Cs ratio, or Na/OH ratio over the range tested. However, the Cs loading kinetics were significantly impacted by the linear load velocity. These results indicated that at the test temperature, the adsorption of cesium is strongly dependent on mass transfer through the film and not significantly impacted by interparticle diffusion. The Cs uptake kinetics were similar between the 5 M Na and 8 M Na simulants indicating that WTP should not have an issue with the Cs loading kinetics in higher Na concentration streams up to 8 M Na being processed through the ion exchange columns. However, there will be a difference in that at higher Na levels, the overall Cs uptake will be lower. Also, the amount of free OH present did not appear to have any effect on the Cs loading in the columns under the conditions tested.

The Cs ion exchange columns were loaded with a 5 M Na simulant initially. The columns were then cycled through several loading and elution tests. After a total of four cycles the columns were loaded with the same 5 M Na feed as used initially. The level of Cs loading on the resin was then compared. It was found that with the cycles kept at 55°C or lower there didn't appear to be any resin degradation with the kinetics and loading capacity essentially the same. However, for the tests performed continually at 60°C and higher in the 336-hour loading cycle, the resin definitely degraded in loading capacity although the initial loading kinetics remained essentially the same. Therefore, in order to avoid resin loading kinetics degradation, the loading temperature should probably be kept at 55°C or lower giving WTP restricted operating range of temperatures or the need to replace resin much more frequently.

The Cs ion exchange columns were held at varying temperatures from 45°C to 75°C for 14 to 30 days with feed being passed through them at very slow rates. Samples were taken periodically to assess the loading of the resin. Testing at elevated temperatures showed that the resin does degrade and loading capacity is reduced at and above 45°C. Above 60°C the resin appears to not load at all. It was observed that the resin disintegrated at 75°C and it partially disintegrated at 65°C, which caused the column to plug on both tests causing them to be aborted after 14 days. These results indicate that WTP will lose resin loading capacity if the ion exchange process is performed above 25°C and the resin will disintegrate above 65°C. Therefore, WTP will have restricted operating range of temperatures to perform its ion exchange process with this resin. PNNL and WTP are currently evaluating the limits of the resin in further detail to determine the operating range of temperatures for the resin.

Small SRF resin samples were contacted with 0.5 M HNO_3 for 70 days at 25°C, 45°C, and 55°C. One SRF resin sample was contacted with de-ionized water for 70 days at 25°C as the baseline. It was found that the loading of the resin afterwards was significantly affected at 45°C while the resin held at 55°C dissolved and could not be loaded. The resin held at 25°C showed no effect on the subsequent loading. Again, WTP will have a restricted operating range of temperatures when dealing with the elution of the resin with nitric acid in order to maintain resin loading capacity and avoid the disintegration of the resin.

A kinetics test was performed with the same simulant as was used in Column A1 under the same conditions with the only difference being the presence of several volatile organics. When compared to

Column A1, the presence of organics did not appear to have an effect on the Cs loading capacity or kinetics at 45°C. The Cs loading kinetics were essentially the same as well as the loading capacity. This indicates that organics should not be a factor during ion exchange operation for the WTP.

In an attempt to understand how the parameter changes affected the kinetic behavior, the ion exchange experiments were modeled using VERSE-LC to provide insight on the kinetics of the ion exchange experiments described in this report. In general, the following conclusions can be drawn:

- Increased sodium content slows down the adsorption/desorption as sodium competes with cesium for resin active sites. However, simulations indicated that 5 and 8 M sodium have very similar adsorption/desorption rates indicating that they are too high to observe a difference.
- Temperature did not strongly impact adsorption/desorption rate constants.
- Contrary to expectation, the flow rate had a strong effect on the adsorption/desorption rate constants that is outside usual mass transfer mechanisms. This was speculated to arise from channeling in the column, convectively-enhanced pore diffusion of cesium, or some other unknown mechanism that is not currently a part of the model.
- The hydroxide concentration has little or no effect on adsorption and desorption above a concentration of 1 M.
- As a column is used over time, it will reach steady-state faster during each subsequent processing cycle. The steady-state will have a lower cesium capacity.
- There were some limitations to using the VERSE-LC model that could be mitigated with additional time. First, the model returned some kinetic results that were not expected (in particular, results relating to the effect of flow rate). This requires further exploration to match the column physics better. Second, the interface of the software was not conducive to a more automated minimization routine. Third, the accuracy of the results could also be improved with better input data, in particular a good estimate of the maximum solute capacity for cesium and accurate measurement of the physical properties of the solution (viscosity and diffusion coefficients in particular). Finally, a more complex model could be built that incorporates some of the ignored species such as Rb^+, K^+, and Na^+ that compete with Cs^+ for adsorption sites on the resin.

The overall conclusions from this testing were:

- The Cs uptake kinetics were similar between the 5 M Na and 8 M Na simulants indicating that WTP should not have an issue with the Cs loading kinetics in higher Na concentration streams up to 8 M Na being processed through the ion exchange columns.
- In order to avoid resin loading kinetics degradation, the loading temperature should probably be kept at 55°C or lower giving WTP restricted operating range of temperatures or the need to replace resin much more frequently.
- These results indicate that WTP will lose resin loading capacity if the ion exchange process is performed above 25°C and the resin will disintegrate above 65°C. Therefore, WTP will have restricted operating range of temperatures to perform its ion exchange process with this resin. PNNL and WTP are currently evaluating the limits of the resin in further detail to determine the operating range of temperatures for the resin.

- The presence of organics did not appear to have an effect on the Cs loading capacity or kinetics at 45°C. The Cs loading kinetics were essentially the same as well as the loading capacity. This indicates that organics should not be a factor during ion exchange operation for the WTP.

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Appendix A: Column Sampling Information

Table A.1. Datasheet for Column A1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
A1-PT-DIW1	20	45	0.09	10/25/10 21:05	10/25/10 23:35	1.10	dark red	NA	8.34	23.02	14.68	NA	NA	NA
A1-PT-ACID	20	45	0.09	10/26/10 8:00	10/26/10 10:40	0.85	orange	45.4	8.37	23.18	14.81	NA	NA	NA
A1-PT-DIW2	20	45	0.09	10/26/10 11:16	10/26/10 12:16	0.85	orange	41.0	8.36	13.76	5.40	NA	NA	NA
A1-PT-NaOH	20	45	0.09	10/26/10 12:24	10/26/10 14:24	1.10	dark red	46.7	8.28	19.10	10.82	NA	NA	NA
A1-LD-0	20	45	0.09	10/27/10 6:57	10/27/10 6:57	NA	dark red	44.5	NA	NA	NA	8.53	11.33	2.80
Loading (LD) Phase Start Date/Time:				10/27/10 7:03										
A1-LD-006	20	45	10.62	10/27/10 7:09	10/27/10 7:09	NA	dark red	41.6	NA	NA	NA	8.43	11.48	3.05
A1-LD-012	20	45	10.62	10/27/10 7:15	10/27/10 7:15	NA	dark red	41.1	NA	NA	NA	8.64	11.38	2.74
A1-LD-018	20	45	10.62	10/27/10 7:21	10/27/10 7:21	NA	dark red	41.5	NA	NA	NA	8.48	11.31	2.83
A1-LD-024	20	45	10.62	10/27/10 7:27	10/27/10 7:27	NA	dark red	42.2	NA	NA	NA	8.48	11.42	2.94
A1-LD-036	20	45	10.62	10/27/10 7:39	10/27/10 7:39	NA	dark red	43.4	NA	NA	NA	8.35	10.96	2.61
A1-LD-048	20	45	10.62	10/27/10 7:51	10/27/10 7:51	NA	dark red	44.0	NA	NA	NA	8.53	11.31	2.78
A1-LD-060	20	45	10.62	10/27/10 8:03	10/27/10 8:03	NA	dark red	44.4	NA	NA	NA	8.60	11.43	2.83
A1-LD-080	20	45	10.62	10/27/10 8:23	10/27/10 8:23	NA	dark red	44.8	NA	NA	NA	8.55	11.13	2.58
A1-LD-120	20	45	10.62	10/27/10 9:03	10/27/10 9:03	NA	dark red	45.6	NA	NA	NA	8.47	11.26	2.79
A1-LD-180	20	45	10.62	10/27/10 10:03	10/27/10 10:03	NA	dark red	46.3	NA	NA	NA	8.63	11.48	2.85
A1-LD-240	20	45	10.62	10/27/10 11:03	10/27/10 11:03	NA	dark red	45.2	NA	NA	NA	8.51	11.24	2.73

Table A.1. Datasheet for Column A1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
A1-LD-600	20	45	10.62	10/27/10 17:03	10/27/10 17:03	1.15	dark red	44.3	NA	NA	NA	8.47	11.39	2.92
A1-FD-CP	20	45	0.09	10/27/10 17:15	10/27/10 19:45	1.10	dark red	45.1	8.45	22.89	14.44	NA	NA	NA
A1-FDI-CP	20	45	0.09	10/27/10 21:10	10/27/10 22:40	1.15	very dark red	24.4	8.51	21.69	13.18	NA	NA	NA
A1-AN-CP	20	45	0.09	10/27/10 23:00	10/28/10 00:00	1.15	very dark red	23.8	8.57	13.75	5.18	NA	NA	NA

Table A.2. Datasheet for Column A1 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				10/28/10 6:55										
A1-EL-CP	60	25	0.08	10/28/10 6:55	10/28/10 15:55	0.9	orange	25.3	14.92	57.53	42.61	8.47	15.54	7.07
A1-EDI-CP	20	25	0.09	10/28/10 16:10	10/28/10 17:10	0.9	orange	24.5	8.39	13.65	5.26	NA	NA	NA
A1-RG-CP	20	25	0.09	10/28/10 17:22	10/28/10 19:23	1.2	dark red	25.0	8.64	18.99	10.35	NA	NA	NA

Table A.3. Datasheet for Column A2 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
A2-LD-0	20	45	NA	11/1/10 6:57	11/1/10 6:57	1.2	dark red	47.6	NA	NA	NA	8.55	NA	3.37

Table A.3. Datasheet for Column A2 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
Loading (LD) Phase Start Date/Time:				11/1/10 7:03										
A2-LD-006	20	45	10.62	11/1/10 7:09	11/1/10 7:09	NA	dark red	44.5	NA	NA	NA	8.55	NA	3.21
A2-LD-012	20	45	10.62	11/1/10 7:15	11/1/10 7:15	NA	dark red	43.2	NA	NA	NA	8.52	NA	3.18
A2-LD-018	20	45	10.62	11/1/10 7:21	11/1/10 7:21	NA	dark red	42.6	NA	NA	NA	8.40	NA	2.89
A2-LD-024	20	45	10.62	11/1/10 7:27	11/1/10 7:27	NA	dark red	42.8	NA	NA	NA	8.62	NA	2.41
A2-LD-036	20	45	10.62	11/1/10 7:39	11/1/10 7:39	NA	dark red	43.6	NA	NA	NA	8.42	NA	3.24
A2-LD-048	20	45	10.62	11/1/10 7:51	11/1/10 7:51	NA	dark red	44.3	NA	NA	NA	8.46	NA	3.21
A2-LD-060	20	45	10.62	11/1/10 8:03	11/1/10 8:03	NA	dark red	44.5	NA	NA	NA	8.56	NA	3.26
A2-LD-080	20	45	10.62	11/1/10 8:23	11/1/10 8:23	NA	dark red	44.7	NA	NA	NA	8.53	NA	2.53
A2-LD-120	20	45	10.62	11/1/10 9:03	11/1/10 9:03	NA	dark red	44.5	NA	NA	NA	8.53	NA	3.27
A2-LD-180	20	45	10.62	11/1/10 10:03	11/1/10 10:03	NA	dark red	44.8	NA	NA	NA	8.50	NA	3.16
A2-LD-240	20	45	10.62	11/1/10 11:03	11/1/10 11:03	NA	almost black	45.1	NA	NA	NA	8.63	NA	3.41
A2-LD-600	20	45	10.62	11/1/10 17:03	11/1/10 17:03	1.2	almost black	44.2	NA	NA	NA	8.48	NA	2.99
A2-FD-CP	20	45	0.09	11/1/10 17:13	11/1/10 19:43	1.1	almost black	44.2	8.46	24.37	15.91	NA	NA	NA
A2-FDI-CP	20	25	0.09	11/1/10 20:17	11/1/10 22:47	1.0	very dark red	25.2	8.47	21.71	13.24	NA	NA	NA
A2-AN-CP	20	25	0.09	11/1/10 23:00	11/2/10 00:00	0.9	very dark red	24.9	8.51	13.77	5.26	NA	NA	NA

Table A.4. Datasheet for Column A2 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				11/2/10 7:00										
A2-EL-CP	60	25	0.08	11/2/10 7:00	11/2/10 17:00	0.9	orange	25.4	14.96	62.36	47.40	8.56	17.35	8.79
A2-EDI-CP	20	25	0.09	11/2/10 17:30	11/2/10 18:30	0.9	orange	24.6	8.52	13.76	5.24	NA	NA	NA
A2-RG-CP	20	25	0.09	11/2/10 18:40	11/2/10 20:40	1.1	dark red	25.4	8.55	18.98	10.43	NA	NA	NA

Table A.5. Datasheet for Column A3 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
A3-LD-0	20	45	NA	11/3/10 6:50	11/3/10 6:50	1.1	dark red	46.8	NA	NA	NA	8.46	NA	3.33
Loading (LD) Phase Start Date/Time:				11/3/10 6:58										
A3-LD-006	20	45	7.08	11/3/10 7:04	11/3/10 7:04	NA	dark red	45.5	NA	NA	NA	8.48	NA	3.13
A3-LD-012	20	45	7.08	11/3/10 7:10	11/3/10 7:10	NA	dark red	44.6	NA	NA	NA	8.54	NA	3.18
A3-LD-018	20	45	7.08	11/3/10 7:16	11/3/10 7:16	NA	dark red	44.7	NA	NA	NA	8.49	NA	2.48
A3-LD-024	20	45	7.08	11/3/10 7:22	11/3/10 7:22	NA	dark red	44.9	NA	NA	NA	8.48	NA	2.43
A3-LD-036	20	45	7.08	11/3/10 7:34	11/3/10 7:34	NA	dark red	45.2	NA	NA	NA	8.45	NA	3.42
A3-LD-048	20	45	7.08	11/3/10 7:46	11/3/10 7:46	NA	dark red	45.2	NA	NA	NA	8.59	NA	2.97
A3-LD-060	20	45	7.08	11/3/10 7:58	11/3/10 7:58	NA	dark red	45.0	NA	NA	NA	8.54	NA	3.29
A3-LD-080	20	45	7.08	11/3/10 8:18	11/3/10 8:18	NA	dark red	44.9	NA	NA	NA	8.43	NA	3.26

Table A.5. Datasheet for Column A3 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
A3-LD-120	20	45	7.08	11/3/10 8:58	11/3/10 8:58	NA	dark red	44.9	NA	NA	NA	8.56	NA	3.19
A3-LD-180	20	45	7.08	11/3/10 9:58	11/3/10 9:58	NA	almost black	44.9	NA	NA	NA	8.51	NA	3.28
A3-LD-240	20	45	7.08	11/3/10 10:58	11/3/10 10:58	NA	almost black	45.1	NA	NA	NA	8.51	NA	3.31
A3-LD-600	20	45	7.08	11/3/10 16:58	11/3/10 16:58	1.3	almost black	45.1	NA	NA	NA	8.47	NA	3.20
A3-FD-CP	20	45	0.09	11/3/10 17:05	11/3/10 19:35	1.3	almost black	45.3	8.48	24.24	15.76	NA	NA	NA
A3-FDI-CP	20	25	0.09	11/3/10 19:45	11/3/10 22:15	1.3	almost black	26.9	8.38	21.41	13.03	NA	NA	NA
A3-AN-CP	20	25	0.09	11/3/10 22:22	11/3/10 23:22	1.3	almost black	23.8	8.53	13.78	5.25	NA	NA	NA

Table A.6. Datasheet for Column A3 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				11/4/10 6:53										
A3-EL-CP	60	25	0.08	11/4/10 6:53	11/4/10 16:53	1.0	orange	24.8	14.91	61.81	46.90	8.43	15.00	6.57
A3-EDI-CP	20	25	0.09	11/4/10 17:02	11/4/10 18:02	0.9	orange	23.6	8.52	13.82	5.30	NA	NA	NA
A3-RG-CP	20	25	0.09	11/4/10 18:03	11/4/10 20:23	1.2	dark red	23.4	8.55	20.40	11.85	NA	NA	NA

Table A.7. Datasheet for Column A4 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
A4-LD-0	20	45	NA	11/5/10 6:50	11/5/10 6:50	1.2	dark red	46.0	NA	NA	NA	8.50	NA	3.18
Loading (LD) Phase Start Date/Time:				11/5/10 6:52										
A4-LD-006	20	45	10.62	11/5/10 6:58	11/5/10 6:58	NA	dark red	44.6	NA	NA	NA	8.58	NA	2.72
A4-LD-012	20	45	10.62	11/5/10 7:04	11/5/10 7:04	NA	dark red	44.1	NA	NA	NA	8.54	NA	3.29
A4-LD-018	20	45	10.62	11/5/10 7:10	11/5/10 7:10	NA	dark red	44.2	NA	NA	NA	8.56	NA	3.17
A4-LD-024	20	45	10.62	11/5/10 7:16	11/5/10 7:16	NA	dark red	44.4	NA	NA	NA	8.46	NA	3.16
A4-LD-036	20	45	10.62	11/5/10 7:28	11/5/10 7:28	NA	dark red	44.8	NA	NA	NA	8.54	NA	3.33
A4-LD-048	20	45	10.62	11/5/10 7:40	11/5/10 7:40	NA	dark red	45.3	NA	NA	NA	8.51	NA	3.03
A4-LD-060	20	45	10.62	11/5/10 7:52	11/5/10 7:52	NA	dark red	47.1	NA	NA	NA	8.50	NA	3.08
A4-LD-080	20	45	10.62	11/5/10 8:12	11/5/10 8:12	NA	dark red	47.6	NA	NA	NA	8.45	NA	3.30
A4-LD-120	20	45	10.62	11/5/10 8:52	11/5/10 8:52	NA	dark red	47.0	NA	NA	NA	8.40	NA	3.19
A4-LD-180	20	45	10.62	11/5/10 9:52	11/5/10 9:52	NA	dark red	46.1	NA	NA	NA	8.51	NA	2.81
A4-LD-240	20	45	10.62	11/5/10 10:52	11/5/10 10:52	NA	dark red	45.3	NA	NA	NA	8.44	NA	3.29
A4-LD-600	20	45	10.62	11/5/10 16:52	11/5/10 16:52	1.3	dark red	46.3	NA	NA	NA	8.61	NA	3.22
A4-FD-CP	20	45	0.09	11/5/10 17:00	11/5/10 19:30	1.3	dark red	46.2	8.61	17.09	8.48	NA	NA	NA

Table A.8. Datasheet for Column A4B Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
A4B-LD-0	20	45	NA	11/8/10 8:26	11/8/10 8:26	1.3	dark red	45.1	NA	NA	NA	8.51	NA	3.31
Loading (LD) Phase Start Date/Time:				11/8/10 8:33										
A4B-LD-004	20	45	0.08	11/8/10 12:33	11/8/10 12:33	NA	dark red	45.5	NA	NA	NA	8.41	NA	3.24
A4B-LD-008	20	45	0.08	11/8/10 16:33	11/8/10 16:33	NA	dark red	45.0	NA	NA	NA	8.55	NA	3.29
A4B-LD-012	20	45	0.08	11/8/10 20:33	11/8/10 20:33	NA	dark red	44.9	NA	NA	NA	8.54	NA	3.02
A4B-LD-024	20	45	0.08	11/9/10 8:33	11/9/10 8:33	NA	dark red	44.2	NA	NA	NA	8.54	NA	3.66
A4B-LD-072	20	45	0.08	11/11/10 8:33	11/11/10 8:33	NA	almost black	44.8	NA	NA	NA	8.47	NA	3.35
A4B-LD-120	20	45	0.08	11/13/10 8:33	11/13/10 8:33	NA	almost black	45.0	NA	NA	NA	8.48	NA	3.25
A4B-LD-168	20	45	0.08	11/15/10 8:33	11/15/10 8:33	NA	almost black	45.1	NA	NA	NA	8.59	NA	3.29
A4B-LD-336	20	45	0.08	11/22/10 8:33	11/22/10 8:33	NA	almost black	45.0	NA	NA	NA	8.54	NA	3.15
A4B-LD-504	20	45	0.08	11/29/10 8:33	11/29/10 8:33	NA	almost black	45.1	NA	NA	NA	8.52	NA	3.20
A4B-LD-672	20	45	0.08	12/6/10 8:33	12/6/10 8:33	NA	almost black	45.0	NA	NA	NA	8.56	NA	3.27
A4B-LD-720	20	45	0.08	12/8/10 8:33	12/8/10 8:33	1.4	almost black	45.0	NA	NA	NA	8.50	NA	3.14
A4B-FD-CP	20	45	0.09	12/8/10 11:47	12/8/10 14:17	1.4	almost black	45.1	8.49	21.05	12.56	NA	NA	NA
A4B-FDI-CP	20	25	0.09	12/8/10 14:25	12/8/10 16:55	1.4	almost black	25.0	8.53	18.87	10.34	NA	NA	NA
A4B-AN-CP	20	25	0.09	12/8/10 17:06	12/8/10 18:06	1.4	almost black	24.1	8.40	12.51	4.11	NA	NA	NA

Table A.9. Datasheet for Column A4B Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
Elution (EL) Phase Start Date/Time:				12/9/10 6:50										
A4B-EL-CP	60	25	0.08	12/9/10 6:50	12/9/10 16:51	1.2	orange	24.8	14.94	52.46	37.52	8.51	18.59	10.08
A4B-EDI-CP	20	25	0.08	12/9/10 17:08	12/9/10 18:08	1.1	orange	24.0	8.47	12.15	3.68	NA	NA	NA
A4B-RG-CP	20	25	0.09	12/9/10 18:20	12/9/10 21:20	1.3	dark red	24.3	8.60	20.88	12.28	NA	NA	NA

Table A.10. Datasheet for Column A5 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
A5-LD-0	20	45	NA	1/4/11 6:56	1/4/11 6:56	1.8	dark brown	42.9	NA	NA	NA	8.59	11.46	2.87
Loading (LD) Phase Start Date/Time:				1/4/11 7:03										
A5-LD-006	20	45	10.62	1/4/11 7:09	1/4/11 7:09	NA	dark brown	41.4	NA	NA	NA	8.49	11.35	2.86
A5-LD-012	20	45	10.62	1/4/11 7:15	1/4/11 7:15	NA	dark brown	40.8	NA	NA	NA	8.40	11.13	2.73
A5-LD-018	20	45	10.62	1/4/11 7:21	1/4/11 7:21	NA	dark brown	40.7	NA	NA	NA	8.43	11.26	2.83
A5-LD-024	20	45	10.62	1/4/11 7:27	1/4/11 7:27	NA	dark brown	41.1	NA	NA	NA	8.39	11.41	3.02
A5-LD-036	20	45	10.62	1/4/11 7:39	1/4/11 7:39	NA	dark brown	41.5	NA	NA	NA	8.48	11.43	2.95
A5-LD-048	20	45	10.62	1/4/11 7:51	1/4/11 7:51	NA	dark brown	42.6	NA	NA	NA	8.50	11.42	2.92
A5-LD-060	20	45	10.62	1/4/11 8:03	1/4/11 8:03	NA	dark brown	43.2	NA	NA	NA	8.69	11.52	2.83
A5-LD-080	20	45	10.62	1/4/11 8:23	1/4/11 8:23	NA	dark brown	43.8	NA	NA	NA	8.48	11.12	2.64

Table A.10. Datasheet for Column A5 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
A5-LD-120	20	45	10.62	1/4/11 9:03	1/4/11 9:03	NA	lighter brown	43.9	NA	NA	NA	8.51	11.28	2.77
A5-LD-180	20	45	10.62	1/4/11 10:03	1/4/11 10:03	NA	lighter brown	44.0	NA	NA	NA	8.50	11.38	2.88
A5-LD-240	20	45	10.62	1/4/11 11:03	1/4/11 11:03	NA	almost black	44.0	NA	NA	NA	8.47	11.39	2.92
A5-LD-600	20	45	10.62	1/4/11 17:03	1/4/11 17:03	NA	almost black	44.1	NA	NA	NA	8.44	11.42	2.98
A5-LD-900	20	45	10.62	1/4/11 22:03	1/4/11 22:03	NA	almost black	45.8	NA	NA	NA	8.53	11.84	3.31
A5-LD-1200	20	45	10.62	1/5/11 3:03	1/5/11 3:03	NA	almost black	45.6	NA	NA	NA	8.37	11.53	3.16
A5-FD-CP	20	45	0.09	1/5/11 3:20	1/5/11 5:50	1.7	almost black	44.4	8.54	22.92	14.38	NA	NA	NA
A5-FDI-CP	20	25	0.09	1/5/11 6:10	1/5/11 8:40	1.7	almost black	24.8	8.41	21.38	12.97	NA	NA	NA
A5-AN-CP	20	25	0.09	1/5/11 8:45	1/5/11 9:51	1.7	dark brown	24.5	8.49	14.30	5.81	NA	NA	NA

Table A.11. Datasheet for Column A5 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				1/5/11 22:04										
A5-EL-CP	60	25	0.08	1/5/11 22:04	1/6/11 9:04	1.4	reddish orange	24.6	14.94	65.60	50.66	8.44	21.13	12.69
A5-EDI-CP	20	25	0.09	1/6/11 9:10	1/6/11 10:13	1.3	reddish orange	24.1	8.25	13.56	5.31	NA	NA	NA

Table A.12. Datasheet for Column B1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
B1-PT-DIW1	20	25	0.09	1/10/11 7:05	1/10/11 9:39	1.2	reddish orange	23.9	8.45	21.20	12.75	NA	NA	NA
B1-PT-ACID	20	25	0.09	1/10/11 10:20	1/10/11 13:20	0.9	orange	24.0	8.55	23.72	15.17	NA	NA	NA
B1-PT-DIW2	20	25	0.09	1/10/11 13:25	1/10/11 14:34	0.9	orange	23.9	8.52	14.22	5.70	NA	NA	NA
B1-PT-NaOH	20	25	0.09	1/10/11 14:41	1/10/11 16:41	1.1	dark red	24.1	8.52	18.80	10.28	NA	NA	NA
B1-LD-0	20	50	NA	1/11/11 6:57	1/11/11 6:57	1.1	dark red	48.6	NA	NA	NA	8.49	11.39	2.90
Loading (LD) Phase Start Date/Time:				1/11/11 7:02										
B1-LD-006	20	50	10.62	1/11/11 7:09	1/11/11 7:09	NA	dark red	45.5	NA	NA	NA	8.45	11.20	2.75
B1-LD-012	20	50	10.62	1/11/11 7:14	1/11/11 7:14	NA	dark red	45.4	NA	NA	NA	8.50	11.39	2.89
B1-LD-018	20	50	10.62	1/11/11 7:20	1/11/11 7:20	NA	dark red	45.8	NA	NA	NA	8.37	11.35	2.98
B1-LD-024	20	50	10.62	1/11/11 7:26	1/11/11 7:26	NA	dark red	46.3	NA	NA	NA	8.46	11.45	2.99
B1-LD-036	20	50	10.62	1/11/11 7:38	1/11/11 7:38	NA	dark red	47.6	NA	NA	NA	8.57	11.37	2.80
B1-LD-048	20	50	10.62	1/11/11 7:50	1/11/11 7:50	NA	dark red	49.0	NA	NA	NA	8.47	11.48	3.01
B1-LD-060	20	50	10.62	1/11/11 8:02	1/11/11 8:02	NA	almost black	49.6	NA	NA	NA	8.51	11.58	3.07
B1-LD-080	20	50	10.62	1/11/11 8:22	1/11/11 8:22	NA	almost black	49.9	NA	NA	NA	8.52	11.48	2.96
B1-LD-120	20	50	10.62	1/11/11 9:02	1/11/11 9:02	NA	almost black	49.6	NA	NA	NA	8.56	11.52	2.96
B1-LD-180	20	50	10.62	1/11/11 10:02	1/11/11 10:02	NA	almost black	49.5	NA	NA	NA	8.54	11.48	2.94
B1-LD-240	20	50	10.62	1/11/11 11:06	1/11/11 11:06	NA	almost black	49.3	NA	NA	NA	8.51	11.46	2.95

Table A.12. Datasheet for Column B1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
B1-LD-600	20	50	10.62	1/11/11 17:02	1/11/11 17:02	NA	almost black	49.6	NA	NA	NA	8.46	11.40	2.94
B1-LD-900	20	50	10.62	1/11/11 22:02	1/11/11 22:02	1.1	dark red	49.4	NA	NA	NA	8.49	11.25	2.76
B1-LD-1200	20	50	10.62	1/12/11 3:02	1/12/11 3:02	1.1	dark red	51.7	NA	NA	NA	8.49	11.16	2.67
B1-FD-CP	20	50	0.09	1/12/11 3:29	1/12/11 5:59	1.1	almost black	49.4	8.55	22.96	14.41	NA	NA	NA
B1-FDI-CP	20	25	0.09	1/12/11 6:02	1/12/11 8:32	1.1	almost black	24.2	8.54	21.39	12.85	NA	NA	NA
B1-AN-CP	20	25	0.09	1/12/11 9:10	1/12/11 10:10	1.1	dark brown	23.9	8.57	13.73	8.57	NA	NA	NA

Table A.13. Datasheet for Column B1 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
Elution (EL) Phase Start Date/Time:				1/12/11 10:16										
B1-EL-CP	60	25	0.08	1/12/11 10:16	1/12/11 20:16	NA	orange	24.5	14.91	60.33	45.42	8.60	19.30	10.70
B1-EDI-CP	20	25	0.09	1/13/11 1:15	1/13/11 3:45	NA	orange	24.5	8.48	20.66	12.18	NA	NA	NA
B1-RG-CP	20	25	0.09	1/13/11 4:34	1/13/11 6:59	1.1	dark brown	24.3	8.56	20.80	12.24	NA	NA	NA

Table A.14. Datasheet for Column B2 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
B2-LD-0	20	50	NA	1/16/11 21:00	1/16/11 21:00	1.1	dark red	49.6	NA	NA	NA	8.52	11.20	2.68
Loading (LD) Phase Start Date/Time:				1/16/11 21:00										
B2-LD-006	20	50	14.16	1/16/11 21:06	1/16/11 21:06	NA	dark red	48.8	NA	NA	NA	8.42	10.80	2.38
B2-LD-012	20	50	14.16	1/16/11 21:12	1/16/11 21:12	NA	dark red	47.5	NA	NA	NA	8.47	11.35	2.88
B2-LD-018	20	50	14.16	1/16/11 21:18	1/16/11 21:18	NA	dark red	46.8	NA	NA	NA	8.54	11.06	2.52
B2-LD-024	20	50	14.16	1/16/11 21:24	1/16/11 21:24	NA	dark red	46.7	NA	NA	NA	8.33	11.06	2.73
B2-LD-036	20	50	14.16	1/16/11 21:36	1/16/11 21:36	NA	dark red	46.9	NA	NA	NA	8.51	11.01	2.50
B2-LD-048	20	50	14.16	1/16/11 21:48	1/16/11 21:48	NA	dark red	47.0	NA	NA	NA	8.43	11.24	2.81
B2-LD-060	20	50	14.16	1/16/11 22:00	1/16/11 22:00	NA	almost black	47.2	NA	NA	NA	8.47	10.88	2.41
B2-LD-080	20	50	14.16	1/16/11 22:20	1/16/11 22:20	NA	almost black	47.3	NA	NA	NA	8.43	10.92	2.49
B2-LD-120	20	50	14.16	1/16/11 23:00	1/16/11 23:00	NA	almost black	47.6	NA	NA	NA	8.39	11.05	2.66
B2-LD-180	20	50	14.16	1/17/11 00:00	1/17/11 00:00	NA	almost black	47.8	NA	NA	NA	8.52	11.10	2.58
B2-LD-240	20	50	14.16	1/17/11 1:00	1/17/11 1:00	NA	almost black	47.9	NA	NA	NA	8.55	11.30	2.75
B2-LD-600	20	50	14.16	1/17/11 7:03	1/17/11 7:03	NA	almost black	48.5	NA	NA	NA	8.37	11.12	2.75
B2-LD-900	20	50	14.16	1/17/11 12:03	1/17/11 12:03	NA	almost black	48.9	NA	NA	NA	8.45	11.38	2.93
B2-LD-1200	20	50	14.16	1/17/11 17:00	1/17/11 17:00	1.3	almost black	48.2	NA	NA	NA	8.54	11.29	2.75

Table A.14. Datasheet for Column B2 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
B2-FD-CP	20	50	0.09	1/17/11 17:14	1/17/11 19:44	1.3	almost black	51.1	8.42	21.66	13.24	NA	NA	NA
B2-FDI-CP	20	25	0.09	1/17/11 19:55	1/17/11 22:25	1.3	almost black	24.7	8.46	20.59	12.13	NA	NA	NA
B2-AN-CP	20	25	0.09	1/17/11 22:45	1/17/11 23:45	1.3	almost black	24.3	8.48	13.45	4.97	NA	NA	NA

Table A.15. Datasheet for Column B2 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
Elution (EL) Phase Start Date/Time:				1/17/11 23:58										
B2-EL-CP	60	25	0.09	1/7/10 23:58	1/18/11 8:58	0.95	dark red	24.6	14.89	58.68	43.79	8.46	18.68	10.22
B2-EDI-CP	20	25	0.09	1/18/11 9:06	1/18/11 10:06	0.95	dark red	24.1	8.53	13.39	4.86	NA	NA	NA
B2-RG-CP	20	25	0.09	1/18/11 10:12	1/18/11 12:42	1.2	almost black	24.4	8.49	20.69	12.20	NA	NA	NA

Table A.16. Datasheet for Column B3 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
B3-LD-0	20	50	NA	1/18/11 21:13	1/18/11 21:13	1.3	dark red	51.3	NA	NA	NA	8.56	11.33	2.77
Loading (LD) Phase Start Date/Time:				1/18/11 21:13										
B3-LD-006	20	50	7.08	1/18/11 21:19	1/18/11 21:19	NA	dark red	48.9	NA	NA	NA	8.45	11.10	2.65

Table A.16. Datasheet for Column B3 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
B3-LD-012	20	50	7.08	1/18/11 21:25	1/18/11 21:25	NA	dark red	47.3	NA	NA	NA	8.55	11.20	2.65
B3-LD-018	20	50	7.08	1/18/11 21:31	1/18/11 21:31	NA	dark red	46.7	NA	NA	NA	8.55	11.10	2.55
B3-LD-024	20	50	7.08	1/18/11 21:37	1/18/11 21:37	NA	dark red	46.2	NA	NA	NA	8.48	11.29	2.81
B3-LD-036	20	50	7.08	1/18/11 21:49	1/18/11 21:49	NA	dark red	46.0	NA	NA	NA	8.48	11.16	2.68
B3-LD-048	20	50	7.08	1/18/11 22:01	1/18/11 22:01	NA	dark red	46.0	NA	NA	NA	8.38	10.95	2.57
B3-LD-060	20	50	7.08	1/18/11 22:13	1/18/11 22:13	NA	almost black	46.1	NA	NA	NA	8.50	11.06	2.56
B3-LD-080	20	50	7.08	1/18/11 22:33	1/18/11 22:33	NA	almost black	46.2	NA	NA	NA	8.53	11.07	2.54
B3-LD-120	20	50	7.08	1/18/11 23:13	1/18/11 23:13	NA	almost black	46.2	NA	NA	NA	8.49	11.16	2.67
B3-LD-180	20	50	7.08	1/19/11 00:13	1/19/11 00:13	NA	almost black	46.5	NA	NA	NA	8.48	11.10	2.62
B3-LD-240	20	50	7.08	1/19/11 1:13	1/19/11 1:13	NA	almost black	46.6	NA	NA	NA	8.36	10.95	2.59
B3-LD-600	20	50	7.08	1/19/11 7:13	1/19/11 7:13	NA	almost black	50.7	NA	NA	NA	8.55	11.27	2.72
B3-LD-900	20	50	7.08	1/19/11 12:13	1/19/11 12:13	NA	almost black	50.7	NA	NA	NA	8.55	11.29	2.74
B3-LD-1200	20	50	7.08	1/19/11 17:13	1/19/11 17:13	1.3	almost black	50.3	NA	NA	NA	8.54	11.37	2.83
B3-FD-CP	20	50	0.09	1/19/11 17:26	1/19/11 19:56	1.2	almost black	50.9	8.45	21.86	13.41	NA	NA	NA
B3-FDI-CP	20	25	0.09	1/19/11 20:10	1/19/11 22:40	1.2	almost black	24.0	8.54	21.19	12.65	NA	NA	NA
B3-AN-CP	20	25	0.09	1/19/11 22:47	1/19/11 23:47	1.1	almost black	24.2	8.54	13.66	5.12	NA	NA	NA

Table A.17. Datasheet for Column B3 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
Elution (EL) Phase Start Date/Time:				1/19/11 23:54										
B3-EL-CP	60	25	0.08	1/19/11 23:54	1/20/11 9:54	0.9	dark red	24.5	14.91	59.19	44.28	8.50	20.04	11.54
B3-EDI-CP	20	25	0.09	1/20/11 10:00	1/20/11 11:00	0.95	red	24.2	8.49	13.47	4.98	NA	NA	NA
B3-RG-CP	20	25	0.09	1/20/11 11:05	1/20/11 14:05	1.2	dark red	24.5	8.53	23.27	14.74	NA	NA	NA

Table A.18. Datasheet for Column B4 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
B4-LD-0	20	50	NA	1/25/11 7:02	1/25/11 7:02	1.2	dark red	50.3	NA	NA	NA	8.57	NA	3.40
Loading (LD) Phase Start Date/Time:				1/25/11 7:04										
B4-LD-006	20	50	7.08	1/25/11 7:10	1/25/11 7:10	NA	dark red	48.3	NA	NA	NA	8.51	NA	3.10
B4-LD-012	20	50	7.08	1/25/11 7:16	1/25/11 7:16	NA	dark red	47.8	NA	NA	NA	8.53	NA	3.29
B4-LD-018	20	50	7.08	1/25/11 7:22	1/25/11 7:22	NA	dark red	48.0	NA	NA	NA	8.44	NA	2.91
B4-LD-024	20	50	7.08	1/25/11 7:28	1/25/11 7:28	NA	dark red	48.5	NA	NA	NA	8.51	NA	3.24
B4-LD-036	20	50	7.08	1/25/11 7:40	1/25/11 7:40	NA	dark red	49.4	NA	NA	NA	8.55	NA	3.33
B4-LD-048	20	50	7.08	1/25/11 7:52	1/25/11 7:52	NA	dark red	50.0	NA	NA	NA	8.58	NA	2.90
B4-LD-060	20	50	7.08	1/25/11 8:04	1/25/11 8:04	NA	almost black	50.2	NA	NA	NA	8.48	NA	3.37
B4-LD-080	20	50	7.08	1/25/11 8:24	1/25/11 8:24	NA	almost black	50.0	NA	NA	NA	8.53	NA	2.36

Table A.18. Datasheet for Column B4 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
B4-LD-120	20	50	7.08	1/25/11 9:04	1/25/11 9:04	NA	almost black	49.8	NA	NA	NA	8.53	NA	2.63
B4-LD-180	20	50	7.08	1/25/11 10:10	1/25/11 10:10	NA	almost black	49.8	NA	NA	NA	8.52	NA	3.28
B4-LD-240	20	50	7.08	1/25/11 11:04	1/25/11 11:04	NA	almost black	49.7	NA	NA	NA	8.47	NA	3.29
B4-LD-600	20	50	7.08	1/25/11 17:04	1/25/11 17:04	NA	almost black	49.8	NA	NA	NA	8.39	NA	3.11
B4-FD-CP	20	50	0.09	1/25/11 17:15	1/25/11 19:45	1.3	almost black	49.8	8.38	23.58	15.20	NA	NA	NA

Table A.19. Datasheet for Column B4B Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
B4B-LD-0	20	65	NA	1/26/11 8:27	1/26/11 8:27	1.3	almost black	63.3	NA	NA	NA	8.37	NA	2.97
Loading (LD) Phase Start Date/Time:				1/26/11 8:33										
B4B-LD-004	20	65	0.08	1/26/11 12:33	1/26/11 12:33	NA	almost black	64.9	NA	NA	NA	8.52	NA	3.12
B4B-LD-008	20	65	0.08	1/26/11 16:33	1/26/11 16:33	NA	almost black	65.1	NA	NA	NA	8.46	NA	2.99
B4B-LD-012	20	65	0.08	1/26/11 20:33	1/26/11 20:33	NA	almost black	65.2	NA	NA	NA	8.55	NA	3.30
B4B-LD-024	20	65	0.08	1/27/11 8:33	1/27/11 8:33	NA	almost black	65.1	NA	NA	NA	8.48	NA	3.36
B4B-LD-072	20	65	0.08	1/29/11 8:33	1/29/11 8:33	NA	almost black	65.2	NA	NA	NA	8.49	NA	3.53
B4B-LD-120	20	65	0.08	1/31/11 8:37	1/31/11 8:37	NA	almost black	65.5	NA	NA	NA	8.43	NA	3.15

Table A.19. Datasheet for Column B4B Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
B4B-LD-168	20	65	0.08	2/2/11 8:33	2/2/11 8:33	NA	almost black	65.3	NA	NA	NA	8.48	NA	3.43
B4B-LD-336	20	65	0.08	2/9/11 8:33	2/9/11 8:33	NA	almost black	65.5	NA	NA	NA	8.55	NA	3.43
B4B-LD-504	20	65	0.08	2/16/11 8:31	2/16/11 8:31	NA	almost black	66.0	NA	NA	NA	8.47	NA	3.57
B4B-FD-CP	20	65	0.09	2/21/11 13:20	2/21/11 15:50	1.3	almost black	65.2	8.48	23.90	15.42	NA	NA	NA
B4B-FDI-CP	20	25	0.09	2/22/11 14:20	2/22/11 16:50	1.3	almost black	25.8	8.60	23.40	14.80	NA	NA	NA
B4B-AN-CP	20	25	0.09	2/22/11 16:55	2/22/11 17:55	1.3	almost black	25.8	8.57	14.68	6.11	NA	NA	NA

Table A.20. Datasheet for Column B4B Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
Elution (EL) Phase Start Date/Time:				2/23/11 6:43										
B4B-EL-CP	60	25	0.09	2/23/11 6:43	2/23/11 16:43	1.0	blackish red	23.6	14.65	67.80	53.15	8.54	15.71	7.17
B4B-EDI-CP	20	25	0.09	2/23/11 16:55	2/23/11 17:55	1.0	blackish red	23.7	8.36	14.14	5.78	NA	NA	NA
B4B-RG-CP	20	25	0.09	2/23/11 18:12	2/23/11 21:12	1.3	black	23.4	8.38	24.20	15.82	NA	NA	NA

Table A.21. Datasheet for Column B5 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
B5-LD-0	20	50	NA	2/28/11 6:54	2/28/11 6:54	1.65	black	58.7	NA	NA	NA	8.42	11.54	3.12
Loading (LD) Phase Start Date/Time:				2/28/11 6:58										
B5-LD-006	20	50	10.62	2/28/11 7:04	2/28/11 7:04	NA	black	54.5	NA	NA	NA	8.50	11.39	2.89
B5-LD-012	20	50	10.62	2/28/11 7:10	2/28/11 7:10	NA	black	51.9	NA	NA	NA	8.50	11.65	3.15
B5-LD-018	20	50	10.62	2/28/11 7:16	2/28/11 7:16	NA	black	50.3	NA	NA	NA	8.49	11.45	2.96
B5-LD-024	20	50	10.62	2/28/11 7:22	2/28/11 7:22	NA	black	49.2	NA	NA	NA	8.49	11.81	3.32
B5-LD-036	20	50	10.62	2/28/11 7:34	2/28/11 7:34	NA	black	48.0	NA	NA	NA	8.49	11.71	3.22
B5-LD-048	20	50	10.62	2/28/11 7:46	2/28/11 7:46	NA	black	48.2	NA	NA	NA	8.43	11.54	3.11
B5-LD-060	20	50	10.62	2/28/11 7:58	2/28/11 7:58	NA	black	48.3	NA	NA	NA	8.40	11.50	3.10
B5-LD-080	20	50	10.62	2/28/11 8:18	2/28/11 8:18	NA	black	49.5	NA	NA	NA	8.53	11.79	3.26
B5-LD-120	20	50	10.62	2/28/11 8:58	2/28/11 8:58	NA	black	50.3	NA	NA	NA	8.47	11.29	2.82
B5-LD-180	20	50	10.62	2/28/11 9:58	2/28/11 9:58	NA	black	50.3	NA	NA	NA	8.47	11.70	3.23
B5-LD-240	20	50	10.62	2/28/11 10:58	2/28/11 10:58	NA	black	50.3	NA	NA	NA	8.53	11.87	3.34
B5-LD-600	20	50	10.62	2/28/11 16:58	2/28/11 16:58	NA	black	50.4	NA	NA	NA	8.55	12.70	4.15
B5-FD-CP	20	50	0.09	2/28/11 17:07	2/28/11 19:37	NA	black	61.4	8.45	23.24	14.79	NA	NA	NA
B5-FDI-CP	20	25	0.09	2/28/11 20:15	2/28/11 22:45	NA	black	23.9	8.45	21.53	13.08	NA	NA	NA
B5-AN-CP	20	25	0.09	2/28/11 22:51	2/28/11 23:51	NA	black	23.4	8.66	13.94	5.28	NA	NA	NA

Table A.22. Datasheet for Column B5 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				3/1/11 6:53										
B5-EL-CP	60	25	0.08	3/1/11 6:53	3/1/11 16:53	1.55	dark red	23.9	14.94	61.82	46.88	8.46	18.86	10.40
B5-EDI-CP	20	25	0.09	3/1/11 17:15	3/1/11 18:15	1.55	dark red	24.0	8.57	13.87	5.30	NA	NA	NA

Table A.23. Datasheet for Column C1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
C1-PT-DIW1	20	25	0.09	1/10/11 7:05	1/10/11 9:39	0.9	reddish orange	25.2	8.43	16.82	8.39	NA	NA	NA
C1-PT-ACID	20	25	0.09	1/10/11 10:20	1/10/11 13:20	0.8	orange	25.9	8.61	23.14	14.53	NA	NA	NA
C1-PT-DIW2	20	25	0.09	1/10/11 13:25	1/10/11 14:34	0.8	orange	25.4	8.52	14.19	5.67	NA	NA	NA
C1-PT-NaOH	20	25	0.09	1/10/11 14:41	1/10/11 16:41	1.0	dark red	25.7	8.44	18.18	9.74	NA	NA	NA
C1-LD-0	20	50	NA	1/11/11 6:55	1/11/11 6:55	1.1	dark red	48.9	NA	NA	NA	8.35	11.37	3.02
Loading (LD) Phase Start Date/Time:				1/11/11 6:59										
C1-LD-006	20	50	10.62	1/11/11 7:05	1/11/11 7:05	NA	dark red	45.9	NA	NA	NA	8.47	11.46	2.99
C1-LD-012	20	50	10.62	1/11/11 7:11	1/11/11 7:11	NA	dark red	45.0	NA	NA	NA	8.56	11.40	2.84
C1-LD-018	20	50	10.62	1/11/11 7:17	1/11/11 7:17	NA	dark red	45.2	NA	NA	NA	8.55	11.66	3.11
C1-LD-024	20	50	10.62	1/11/11 7:23	1/11/11 7:23	NA	dark red	45.8	NA	NA	NA	8.52	11.60	3.08
C1-LD-036	20	50	10.62	1/11/11 7:35	1/11/11 7:35	NA	dark red	46.9	NA	NA	NA	8.47	11.36	2.89

Table A.23. Datasheet for Column C1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
C1-LD-048	20	50	10.62	1/11/11 7:47	1/11/11 7:47	NA	dark red	48.3	NA	NA	NA	8.52	11.57	3.05
C1-LD-060	20	50	10.62	1/11/11 7:59	1/11/11 7:59	NA	almost black	49.0	NA	NA	NA	8.38	11.29	2.91
C1-LD-080	20	50	10.62	1/11/11 8:19	1/11/11 8:19	NA	almost black	49.6	NA	NA	NA	8.52	11.26	2.74
C1-LD-120	20	50	10.62	1/11/11 8:59	1/11/11 8:59	NA	almost black	49.6	NA	NA	NA	8.40	11.27	2.87
C1-LD-180	20	50	10.62	1/11/11 9:59	1/11/11 9:59	NA	almost black	49.6	NA	NA	NA	8.57	10.86	2.29
C1-LD-240	20	50	10.62	1/11/11 11:06	1/11/11 11:06	NA	almost black	49.6	NA	NA	NA	8.39	11.41	3.02
C1-LD-600	20	50	10.62	1/11/11 16:59	1/11/11 16:59	NA	almost black	49.6	NA	NA	NA	8.52	11.36	2.84
C1-LD-900	20	50	10.62	1/11/11 21:59	1/11/11 21:59	1.15	dark red	48.8	NA	NA	NA	8.48	10.88	2.40
C1-LD-1200	20	50	10.62	1/12/11 2:59	1/12/11 2:59	1.15	dark red	51.4	NA	NA	NA	8.48	11.41	2.93
C1-FD-CP	20	50	0.09	1/12/11 3:24	1/12/11 5:54	1.2	almost black	49.6	8.50	18.93	10.43	NA	NA	NA
C1-FDI-CP	20	25	0.09	1/12/11 5:59	1/12/11 9:07	1.2	almost black	26.6	8.53	15.51	6.98	NA	NA	NA
C1-AN-CP	20	25	0.09	1/12/11 9:10	1/12/11 10:10	1.2	dark brown	25.0	8.57	10.96	2.39	NA	NA	NA

Table A.24. Datasheet for Column C1 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				1/12/11 10:16										
C1-EL-CP	60	25	0.08	1/12/11 10:16	1/13/11 00:16	NA	orange	24.5	24.98	88.82	63.84	8.52	21.56	13.04
C1-EDI-CP	20	25	0.09	1/13/11 1:15	1/13/11 3:45	NA	orange	24.5	8.47	20.31	11.84	NA	NA	NA
C1-RG-CP	20	25	0.09	1/13/11 4:34	1/13/11 6:59	1.1	dark brown	26.4	8.52	18.85	10.33	NA	NA	NA

Table A.25. Datasheet for Column C2 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
C2-LD-0	20	50	NA	1/16/11 21:03	1/16/11 21:03	1.1	dark red	51.3	NA	NA	NA	8.51	10.96	2.45
Loading (LD) Phase Start Date/Time:				1/16/11 21:03										
C2-LD-006	20	50	14.16	1/16/11 21:09	1/16/11 21:09	NA	dark red	49.9	NA	NA	NA	8.51	11.16	2.65
C2-LD-012	20	50	14.16	1/16/11 21:15	1/16/11 21:15	NA	dark red	48.3	NA	NA	NA	8.56	11.16	2.60
C2-LD-018	20	50	14.16	1/16/11 21:21	1/16/11 21:21	NA	dark red	47.8	NA	NA	NA	8.50	11.18	2.68
C2-LD-024	20	50	14.16	1/16/11 21:27	1/16/11 21:27	NA	dark red	48.0	NA	NA	NA	8.49	11.36	2.87
C2-LD-036	20	50	14.16	1/16/11 21:39	1/16/11 21:36	NA	dark red	48.5	NA	NA	NA	8.42	11.01	2.59
C2-LD-048	20	50	14.16	1/16/11 21:51	1/16/11 21:51	NA	dark red	48.7	NA	NA	NA	8.47	11.08	2.61
C2-LD-060	20	50	14.16	1/16/11 22:03	1/16/11 22:00	NA	almost black	48.9	NA	NA	NA	8.48	11.17	2.69
C2-LD-080	20	50	14.16	1/16/11 22:23	1/16/11 22:20	NA	almost black	48.8	NA	NA	NA	8.56	11.05	2.49

Table A.25. Datasheet for Column C2 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
C2-LD-120	20	50	14.16	1/16/11 23:03	1/16/11 23:03	NA	almost black	49.3	NA	NA	NA	8.40	11.07	2.67
C2-LD-180	20	50	14.16	1/17/11 00:03	1/17/11 00:03	NA	almost black	49.4	NA	NA	NA	8.33	10.97	2.64
C2-LD-240	20	50	14.16	1/17/11 1:03	1/17/11 1:00	NA	almost black	49.7	NA	NA	NA	8.51	11.33	2.82
C2-LD-600	20	50	14.16	1/17/11 7:00	1/17/11 7:00	NA	almost black	49.6	NA	NA	NA	8.45	11.46	3.01
C2-LD-900	20	50	14.16	1/17/11 12:01	1/17/11 12:01	NA	almost black	49.7	NA	NA	NA	8.52	11.23	2.71
C2-LD-1200	20	50	14.16	1/17/11 17:03	1/17/11 17:03	1.3	almost black	47.0	NA	NA	NA	8.46	11.30	2.84
C2-FD-CP	20	50	0.09	1/17/11 17:14	1/17/11 19:44	1.3	almost black	50.4	8.42	21.00	12.58	NA	NA	NA
C2-FDI-CP	20	25	0.09	1/17/11 19:55	1/17/11 22:25	1.3	almost black	24.4	8.42	21.46	13.04	NA	NA	NA
C2-AN-CP	20	25	0.09	1/17/11 22:45	1/17/11 23:45	1.3	almost black	24.6	8.46	13.48	5.02	NA	NA	NA

Table A.26. Datasheet for Column C2 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				1/17/11 23:58										
C2-EL-CP	60	25	0.09	1/7/10 23:58	1/18/11 8:58	0.9	dark red	26.9	14.90	59.45	44.55	8.34	17.10	8.76
C2-EDI-CP	20	25	0.09	1/18/11 9:06	1/18/11 10:06	0.9	dark red	25.9	8.53	13.32	4.79	NA	NA	NA
C2-RG-CP	20	25	0.09	1/18/11 10:12	1/18/11 12:42	1.2	almost black	26.5	8.56	20.94	12.38	NA	NA	NA

Table A.27. Datasheet for Column C3 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
C3-LD-0	20	50	NA	1/18/11 21:10	1/18/11 21:10	1.3	dark red	50.9	NA	NA	NA	8.58	11.43	2.85
Loading (LD) Phase Start Date/Time:				1/18/11 21:10										
C3-LD-006	20	50	7.08	1/18/11 21:16	1/18/11 21:19	NA	dark red	50.4	NA	NA	NA	8.47	11.17	2.70
C3-LD-012	20	50	7.08	1/18/11 21:22	1/18/11 21:25	NA	dark red	48.8	NA	NA	NA	8.43	11.04	2.61
C3-LD-018	20	50	7.08	1/18/11 21:28	1/18/11 21:28	NA	dark red	47.9	NA	NA	NA	8.48	11.11	2.63
C3-LD-024	20	50	7.08	1/18/11 21:34	1/18/11 21:37	NA	dark red	47.4	NA	NA	NA	8.58	11.34	2.76
C3-LD-036	20	50	7.08	1/18/11 21:46	1/18/11 21:46	NA	dark red	47.4	NA	NA	NA	8.45	11.29	2.84
C3-LD-048	20	50	7.08	1/18/11 21:58	1/18/11 21:58	NA	dark red	47.7	NA	NA	NA	8.46	11.30	2.84
C3-LD-060	20	50	7.08	1/18/11 22:10	1/18/11 22:10	NA	almost black	48.2	NA	NA	NA	8.49	10.96	2.47
C3-LD-080	20	50	7.08	1/18/11 22:30	1/18/11 22:30	NA	almost black	48.6	NA	NA	NA	8.46	11.05	2.59
C3-LD-120	20	50	7.08	1/18/11 23:10	1/18/11 23:10	NA	almost black	48.7	NA	NA	NA	8.42	11.03	2.61
C3-LD-180	20	50	7.08	1/19/11 00:10	1/19/11 00:10	NA	almost black	49.2	NA	NA	NA	8.51	11.10	2.59
C3-LD-240	20	50	7.08	1/19/11 1:10	1/19/11 1:10	NA	almost black	49.8	NA	NA	NA	8.57	11.26	2.69
C3-LD-600	20	50	7.08	1/19/11 7:10	1/19/11 7:10	NA	almost black	47.7	NA	NA	NA	8.48	11.18	2.70
C3-LD-900	20	50	7.08	1/19/11 12:10	1/19/11 12:10	NA	almost black	48.2	NA	NA	NA	8.49	11.15	2.66
C3-LD-1200	20	50	7.08	1/19/11 17:10	1/19/11 17:10	1.3	almost black	49.2	NA	NA	NA	8.52	11.42	2.90

Table A.27. Datasheet for Column C3 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
C3-FD-CP	20	50	0.09	1/19/11 17:26	1/19/11 19:56	1.2	almost black	49.7	8.38	21.02	12.64	NA	NA	NA
C3-FDI-CP	20	25	0.09	1/19/11 20:10	1/19/11 22:40	1.2	almost black	23.8	8.45	20.98	12.53	NA	NA	NA
C3-AN-CP	20	25	0.09	1/19/11 22:47	1/19/11 23:47	1.1	almost black	25.2	8.57	13.61	5.04	NA	NA	NA

Table A.28. Datasheet for Column C3 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				1/19/11 23:54										
C3-EL-CP	60	25	0.08	1/19/11 23:54	1/20/11 9:54	0.9	dark red	27.0	14.92	59.53	44.61	8.48	21.10	12.62
C3-EDI-CP	20	25	0.09	1/20/11 10:00	1/20/11 11:00	0.95	red	26.0	8.47	13.41	4.94	NA	NA	NA
C3-RG-CP	20	25	0.09	1/20/11 11:05	1/20/11 14:05	1.25	dark red	26.7	8.49	23.27	14.78	NA	NA	NA

Table A.29. Datasheet for Column C4 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
C4-LD-0	20	50	NA	1/25/11 6:55	1/25/11 6:55	1.3	dark red	54.3	NA	NA	NA	8.55	NA	3.60
Loading (LD) Phase Start Date/Time:				1/25/11 7:01										
C4-LD-006	20	50	7.08	1/25/11 7:07	1/25/11 7:07	NA	dark red	50.8	NA	NA	NA	8.50	NA	3.40

Table A.29. Datasheet for Column C4 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
C4-LD-012	20	50	7.08	1/25/11 7:13	1/25/11 7:13	NA	dark red	48.9	NA	NA	NA	8.55	NA	3.37
C4-LD-018	20	50	7.08	1/25/11 7:19	1/25/11 7:19	NA	dark red	48.3	NA	NA	NA	8.48	NA	3.28
C4-LD-024	20	50	7.08	1/25/11 7:25	1/25/11 7:25	NA	dark red	48.2	NA	NA	NA	8.46	NA	3.36
C4-LD-036	20	50	7.08	1/25/11 7:37	1/25/11 7:37	NA	dark red	48.5	NA	NA	NA	8.37	NA	3.28
C4-LD-048	20	50	7.08	1/25/11 7:49	1/25/11 7:49	NA	dark red	49.1	NA	NA	NA	8.41	NA	3.12
C4-LD-060	20	50	7.08	1/25/11 8:01	1/25/11 8:01	NA	almost black	49.6	NA	NA	NA	8.46	NA	2.97
C4-LD-080	20	50	7.08	1/25/11 8:21	1/25/11 8:21	NA	almost black	49.9	NA	NA	NA	8.58	NA	3.44
C4-LD-120	20	50	7.08	1/25/11 9:01	1/25/11 9:01	NA	almost black	50.2	NA	NA	NA	8.48	NA	3.21
C4-LD-180	20	50	7.08	1/25/11 10:10	1/25/11 10:10	NA	almost black	50.1	NA	NA	NA	8.46	NA	3.35
C4-LD-240	20	50	7.08	1/25/11 11:01	1/25/11 11:01	NA	almost black	50.0	NA	NA	NA	8.48	NA	3.16
C4-LD-600	20	50	7.08	1/25/11 17:01	1/25/11 17:01	NA	almost black	50.2	NA	NA	NA	8.44	NA	3.21
C4-FD-CP	20	50	0.09	1/25/11 17:15	1/25/11 19:45	1.3	almost black	51.7	8.39	22.54	14.15	NA	NA	NA

Table A.30. Datasheet for Column C4B Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
C4B-LD-0	20	75	NA	1/26/11 8:25	1/26/11 8:25	1.3	almost black	71.0	NA	NA	NA	8.52	NA	2.65
Loading (LD) Phase Start Date/Time:				1/26/11 8:30										
C4B-LD-004	20	75	0.08	1/26/11 12:30	1/26/11 12:30	NA	almost black	75.5	NA	NA	NA	8.54	NA	2.99
C4B-LD-008	20	75	0.08	1/26/11 16:30	1/26/11 16:30	NA	almost black	75.4	NA	NA	NA	8.51	NA	3.41
C4B-LD-012	20	75	0.08	1/26/11 20:30	1/26/11 20:30	NA	almost black	75.3	NA	NA	NA	8.57	NA	3.38
C4B-LD-024	20	75	0.08	1/27/11 8:30	1/27/11 8:30	NA	almost black	75.5	NA	NA	NA	8.46	NA	3.18
C4B-LD-072	20	75	0.08	1/29/11 8:30	1/29/11 8:30	NA	almost black	75.5	NA	NA	NA	8.51	NA	3.41
C4B-LD-120	20	75	0.08	2/1/11 13:15	2/1/11 13:15	NA	almost black	75.3	NA	NA	NA	8.56	NA	3.04
C4B-LD-168	20	75	0.08	2/3/11 13:15	2/3/11 13:15	NA	almost black	75.2	NA	NA	NA	8.49	NA	3.30
C4B-LD-336	20	75	0.08	2/10/11 13:17	2/10/11 13:17	NA	black	74.6	NA	NA	NA	8.44	NA	3.08
C4B-FD-CP	20	75	0.09	2/21/11 13:20	2/21/11 15:50	1.3	almost black	74.8	8.47	22.16	13.69	NA	NA	NA
C4B-FDI-CP	20	25	0.09	2/22/11 14:20	2/22/11 16:50	1.3	almost black	23.8	8.44	22.07	13.63	NA	NA	NA
CB4-AN-CP	20	25	0.09	2/22/11 16:55	2/22/11 17:55	1.3	almost black	23.4	8.46	14.17	5.71	NA	NA	NA

Table A.31. Datasheet for Column C4B Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
Elution (EL) Phase Start Date/Time:				2/23/11 6:43										
C4B-EL-CP	60	25	0.09	2/23/11 6:43	2/23/11 16:43	1.0	blackish red	23.1	14.58	63.85	49.27	8.46	15.87	7.41
C4B-EDI-CP	20	25	0.09	2/23/11 16:55	2/23/11 17:55	1.0	blackish red	23.4	8.35	13.70	5.35	NA	NA	NA
C4B-RG-CP	20	25	0.09	2/23/11 18:12	2/23/11 21:12	1.3	black	23.3	8.38	23.22	14.84	NA	NA	NA

Table A.32. Datasheet for Column C5 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
C5-LD-0	20	50	NA	2/28/11 6:51	2/28/11 6:51	1.6	black	60.5	NA	NA	NA	8.49	11.33	2.84
Loading (LD) Phase Start Date/Time:				2/28/11 6:55										
C5-LD-006	20	50	10.62	2/28/11 7:01	2/28/11 7:04	NA	black	55.4	NA	NA	NA	8.55	12.05	3.50
C5-LD-012	20	50	10.62	2/28/11 7:07	2/28/11 7:07	NA	black	52.4	NA	NA	NA	8.43	11.55	3.12
C5-LD-018	20	50	10.62	2/28/11 7:13	2/28/11 7:13	NA	black	49.8	NA	NA	NA	8.52	11.95	3.43
C5-LD-024	20	50	10.62	2/28/11 7:19	2/28/11 7:19	NA	black	48.3	NA	NA	NA	8.48	11.59	3.11
C5-LD-036	20	50	10.62	2/28/11 7:31	2/28/11 7:31	NA	black	46.9	NA	NA	NA	8.48	11.97	3.49
C5-LD-048	20	50	10.62	2/28/11 7:43	2/28/11 7:43	NA	black	47.1	NA	NA	NA	8.44	11.69	3.25
C5-LD-060	20	50	10.62	2/28/11 7:55	2/28/11 7:55	NA	black	47.5	NA	NA	NA	8.45	11.65	3.20
C5-LD-080	20	50	10.62	2/28/11 8:15	2/28/11 8:15	NA	black	49.2	NA	NA	NA	8.46	11.61	3.15
C5-LD-120	20	50	10.62	2/28/11 8:55	2/28/11 8:55	NA	black	50.3	NA	NA	NA	8.40	11.56	3.16
C5-LD-180	20	50	10.62	2/28/11 9:55	2/28/11 9:55	NA	black	50.2	NA	NA	NA	8.54	11.87	3.33
C5-LD-240	20	50	10.62	2/28/11 10:55	2/28/11 10:58	NA	black	50.2	NA	NA	NA	8.42	11.51	3.09
C5-LD-600	20	50	10.62	2/28/11 16:55	2/28/11 16:55	NA	black	50.3	NA	NA	NA	8.47	12.58	4.11
C5-FD-CP	20	50	0.09	2/28/11 17:07	2/28/11 19:37	NA	black	60.4	8.41	21.18	12.77	NA	NA	NA

Table A.32. Datasheet for Column C5 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
C5-FDI-CP	20	25	0.09	2/28/11 20:15	2/28/11 22:45	NA	black	25.8	8.50	20.34	11.84	NA	NA	NA
C5-AN-CP	20	25	0.09	2/28/11 22:51	2/28/11 23:51	NA	black	24.5	8.55	13.20	4.65	NA	NA	NA

Table A.33. Datasheet for Column C5 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
Elution (EL) Phase Start Date/Time:				3/1/11 6:53										
C5-EL-CP	60	25	0.08	3/1/11 6:53	3/1/11 16:53	1.0	dark red	25.3	14.93	56.61	41.68	8.36	20.63	12.27
C5-EDI-CP	20	25	0.09	3/1/11 17:15	3/1/11 18:15	1.0	dark red	25.6	8.47	13.13	4.66	NA	NA	NA

Table A.34. Datasheet for Column D1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
D1-PT-DIW1	20	25	0.09	10/14/10 8:45	10/14/10 11:15	1.1	dark red	24.5	8.60	21.18	12.58	NA	NA	NA
D1-PT-ACID	20	25	0.09	10/14/10 11:24	10/14/10 14:07	0.95	orange	24.7	8.53	23.06	14.53	NA	NA	NA
D1-PT-DIW2	20	25	0.09	10/14/10 14:33	10/14/10 15:33	0.9	orange	22.2	8.55	13.72	5.17	NA	NA	NA
D1-PT-NaOH	20	25	0.09	10/14/10 15:38	10/14/10 17:38	1.1	dark red	20.6	8.55	18.86	10.31	NA	NA	NA
D1-LD-0	20	25	NA	10/18/10 7:07	10/18/10 7:08	1.1	dark red	24.2	NA	NA	NA	8.59	11.68	3.09
Loading (LD) Phase Start Date/Time:				10/18/10 7:12										

Table A.34. Datasheet for Column D1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
D1-LD-006	20	25	10.62	10/18/10 7:18	10/18/10 7:18	NA	dark red	23.1	NA	NA	NA	8.51	11.46	2.95
D1-LD-012	20	25	10.62	10/18/10 7:24	10/18/10 7:24	NA	darker red	22.5	NA	NA	NA	8.54	11.55	3.01
D1-LD-018	20	25	10.62	10/18/10 7:30	10/18/10 7:30	NA	darker red	22.5	NA	NA	NA	8.55	11.69	3.14
D1-LD-024	20	25	10.62	10/18/10 7:36	10/18/10 7:36	NA	darker red	22.7	NA	NA	NA	8.56	11.57	3.01
D1-LD-036	20	25	10.62	10/18/10 7:48	10/18/10 7:48	NA	very dark red	23.5	NA	NA	NA	8.53	11.66	3.13
D1-LD-048	20	25	10.62	10/18/10 8:00	10/18/10 8:00	NA	very dark red	24.1	NA	NA	NA	8.50	11.58	3.08
D1-LD-060	20	25	10.62	10/18/10 8:12	10/18/10 8:13	NA	very dark red	24.6	NA	NA	NA	8.46	11.34	2.88
D1-LD-080	20	25	10.62	10/18/10 8:32	10/18/10 8:32	NA	very dark red	24.9	NA	NA	NA	8.51	11.50	2.99
D1-LD-120	20	25	10.62	10/18/10 9:12	10/18/10 9:12	NA	very dark red	25.2	NA	NA	NA	8.58	11.65	3.07
D1-LD-180	20	25	10.62	10/18/10 10:13	10/18/10 10:13	NA	very dark red	25.2	NA	NA	NA	8.57	11.39	2.82
D1-LD-240	20	25	10.62	10/18/10 11:12	10/18/10 11:12	NA	very dark red	25.9	NA	NA	NA	8.47	11.46	2.99
D1-LD-600	20	25	10.62	10/18/10 17:12	10/18/10 17:12	1.2	very dark red	25.5	NA	NA	NA	8.50	11.47	2.97

Table A.34. Datasheet for Column D1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
D1-FD-CP	20	25	0.09	10/18/10 17:18	10/18/10 19:48	1.2	very dark red	25.3	8.48	22.16	13.68	NA	NA	NA
D1-FDI-CP	20	25	0.09	10/18/10 19:55	10/18/10 22:25	1.15	very dark red	25.2	8.57	20.51	11.94	NA	NA	NA
D1-AN-CP	20	25	0.09	10/18/10 22:36	10/18/10 23:36	1.1	very dark red	25.5	8.55	13.29	4.74	NA	NA	NA

Table A.35. Datasheet for Column D1 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				10/19/10 6:57										
D1-EL-CP	60	25	0.08	10/19/10 6:57	10/19/10 15:57	1.0	orange	25.3	14.90	54.32	39.42	8.49	11.05	2.56
D1-EDI-CP	20	25	0.08	10/19/10 16:21	10/19/10 17:21	1.0	orange	24.6	8.48	12.70	4.22	NA	NA	NA
D1-RG-CP	20	25	0.08	10/19/10 17:28	10/19/10 19:58	1.1	dark red	25.4	8.52	20.44	11.92	NA	NA	NA

Table A.36. Datasheet for Column E1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
E1-PT-DIW1	20	50	0.09	10/20/10 15:24	10/20/10 17:54	1. 0	dark red	50.1	8.48	20.58	12.10	NA	NA	NA
E1-PT-ACID	20	50	0.09	10/21/10 6:52	10/21/10 10:37	1.0	orange	50.0	8.38	20.69	12.31	NA	NA	NA

Table A.36. Datasheet for Column E1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
E1-PT-DIW2	20	50	0.09	10/21/10 11:15	10/21/10 12:15	1.0	orange	NA	8.42	12.52	4.10	NA	NA	NA
E1-PT-NaOH	20	50	0.09	10/21/10 14:15	10/21/10 16:15	1.1	dark red	50.3	8.48	16.78	8.30	NA	NA	NA
E1-LD-0	20	50	NA	10/25/10 6:52	10/25/10 6:52	NA	dark red	51.3	NA	NA	NA	8.39	11.55	3.16
Loading (LD) Phase Start Date/Time:				10/25/10 7:00										
E1-LD-006	20	50	10.62	10/25/10 7:06	10/25/10 7:06	NA	dark red	46.6	NA	NA	NA	8.58	11.60	3.02
E1-LD-012	20	50	10.62	10/25/10 7:12	10/25/10 7:12	NA	dark red	45.3	NA	NA	NA	8.57	11.67	3.10
E1-LD-018	20	50	10.62	10/25/10 7:18	10/25/10 7:18	NA	dark red	45.8	NA	NA	NA	8.56	11.61	3.05
E1-LD-024	20	50	10.62	10/25/10 7:24	10/25/10 7:24	NA	dark red	46.3	NA	NA	NA	8.57	11.69	3.12
E1-LD-036	20	50	10.62	10/25/10 7:36	10/25/10 7:36	NA	dark red	48.2	NA	NA	NA	8.42	11.14	2.72
E1-LD-048	20	50	10.62	10/25/10 7:48	10/25/10 7:48	NA	dark red	49.5	NA	NA	NA	8.56	11.64	3.08
E1-LD-060	20	50	10.62	10/25/10 8:00	10/25/10 8:00	NA	dark red	49.8	NA	NA	NA	8.51	11.72	3.21
E1-LD-080	20	50	10.62	10/25/10 8:20	10/25/10 8:20	NA	dark red	49.8	NA	NA	NA	8.34	11.17	2.83
E1-LD-120	20	50	10.62	10/25/10 9:00	10/25/10 9:00	NA	dark red	49.8	NA	NA	NA	8.46	11.64	3.18
E1-LD-180	20	50	10.62	10/25/10 10:00	10/25/10 10:00	NA	dark red	49.6	NA	NA	NA	8.49	11.45	2.96
E1-LD-240	20	50	10.62	10/25/10 11:00	10/25/10 11:00	NA	very dark red	49.8	NA	NA	NA	8.44	10.88	2.44
E1-LD-600	20	50	10.62	10/25/10 17:00	10/25/10 17:00	1.1	very dark red	49.9	NA	NA	NA	8.58	11.52	2.96

Table A.36. Datasheet for Column E1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
E1-FD-CP	20	50	0.09	10/25/10 17:07	10/25/10 19:37	1.1	very dark red	49.6	8.35	21.98	13.63	NA	NA	NA
E1-FDI-CP	20	25	0.09	10/25/10 20:10	10/25/10 22:40	1.1	very dark red	25.2	8.52	20.02	11.50	NA	NA	NA
E1-AN-CP	20	25	0.09	10/25/10 23:00	10/26/10 00:00	1.1	very dark red	25.7	8.47	13.10	4.63	NA	NA	NA

Table A.37. Datasheet for Column E1 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				10/26/10 7:05										
E1-EL-CP	60	25	0.08	10/26/10 7:05	10/26/10 16:05	0.9	orange	27.3	14.98	52.14	37.16	8.60	16.34	7.74
E1-EDI-CP	20	25	0.09	10/26/10 16:21	10/26/10 17:21	0.95	orange	25.2	8.44	12.96	4.52	NA	NA	NA
E1-RG-CP	20	25	0.09	10/26/10 17:30	10/26/10 19:50	1.1	dark red	25.4	8.46	19.13	10.67	NA	NA	NA

Table A.38. Datasheet for Column E2 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
E2-LD-0	20	50	NA	10/27/10 6:56	10/27/10 6:56	NA	dark red	48.3	NA	NA	NA	8.58	NA	3.54
Loading (LD) Phase Start Date/Time:				10/27/10 7:00										

Table A.38. Datasheet for Column E2 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
E2-LD-006	20	50	10.62	10/27/10 7:06	10/27/10 7:06	NA	dark red	45.6	NA	NA	NA	8.51	NA	3.11
E2-LD-012	20	50	10.62	10/27/10 7:12	10/27/10 7:12	NA	dark red	45.1	NA	NA	NA	8.55	NA	3.31
E2-LD-018	20	50	10.62	10/27/10 7:18	10/27/10 7:18	NA	dark red	45.8	NA	NA	NA	8.52	NA	3.45
E2-LD-024	20	50	10.62	10/27/10 7:24	10/27/10 7:24	NA	dark red	46.4	NA	NA	NA	8.57	NA	3.16
E2-LD-036	20	50	10.62	10/27/10 7:36	10/27/10 7:36	NA	dark red	48.2	NA	NA	NA	8.47	NA	3.41
E2-LD-048	20	50	10.62	10/27/10 7:48	10/27/10 7:48	NA	dark red	49.3	NA	NA	NA	8.53	NA	3.22
E2-LD-060	20	50	10.62	10/27/10 8:00	10/27/10 8:00	NA	dark red	49.9	NA	NA	NA	8.47	NA	3.08
E2-LD-080	20	50	10.62	10/27/10 8:20	10/27/10 8:20	NA	dark red	50.4	NA	NA	NA	8.42	NA	3.31
E2-LD-120	20	50	10.62	10/27/10 9:00	10/27/10 9:00	NA	dark red	50.9	NA	NA	NA	8.43	NA	3.23
E2-LD-180	20	50	10.62	10/27/10 10:00	10/27/10 10:00	NA	dark red	50.6	NA	NA	NA	8.41	NA	3.24
E2-LD-240	20	50	10.62	10/27/10 11:00	10/27/10 11:00	NA	dark red	50.0	NA	NA	NA	8.46	NA	3.20
E2-LD-600	20	50	10.62	10/27/10 17:00	10/27/10 17:00	1.2	dark red	49.1	NA	NA	NA	8.45	NA	3.36
E2-FD-CP	20	50	0.09	10/27/10 17:15	10/27/10 17:15	1.2	dark red	50.2	8.47	22.75	14.28	NA	NA	NA
E2-FDI-CP	20	25	0.09	10/27/10 20:10	10/27/10 22:40	1.25	very dark red	25.6	8.50	20.21	11.71	NA	NA	NA
E2-AN-CP	20	25	0.09	10/27/10 23:00	10/28/10 00:00	1.25	very dark red	23.9	8.42	13.08	4.66	NA	NA	NA

Table A.39. Datasheet for Column E2 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				10/28/10 6:55										
E2-EL-CP	60	25	0.08	10/28/10 6:55	10/28/10 15:55	1.0	orange	26.5	14.88	55.65	40.77	8.49	13.78	5.29
E2-EDI-CP	20	25	0.09	10/28/10 16:10	10/28/10 17:10	1.0	orange	24.0	8.61	11.73	3.12	NA	NA	NA
E2-RG-CP	20	25	0.09	10/28/10 17:22	10/28/10 20:12	1.2	dark red	25.2	8.41	19.20	10.79	NA	NA	NA

Table A.40. Datasheet for Column E3 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
E3-LD-0	20	50	NA	11/1/10 6:55	11/1/10 6:55	1.2	dark red	54.2	NA	NA	NA	8.48	NA	3.57
Loading (LD) Phase Start Date/Time:				11/1/10 7:00										
E3-LD-006	20	50	7.08	11/1/10 7:06	11/1/10 7:06	NA	dark red	51.6	NA	NA	NA	8.47	NA	3.20
E3-LD-012	20	50	7.08	11/1/10 7:12	11/1/10 7:12	NA	dark red	50.2	NA	NA	NA	8.42	NA	3.19
E3-LD-018	20	50	7.08	11/1/10 7:18	11/1/10 7:18	NA	dark red	49.2	NA	NA	NA	8.56	NA	3.13
E3-LD-024	20	50	7.08	11/1/10 7:24	11/1/10 7:24	NA	dark red	48.9	NA	NA	NA	8.59	NA	3.12
E3-LD-036	20	50	7.08	11/1/10 7:36	11/1/10 7:36	NA	dark red	49.8	NA	NA	NA	8.55	NA	3.07
E3-LD-048	20	50	7.08	11/1/10 7:48	11/1/10 7:48	NA	dark red	50.5	NA	NA	NA	8.49	NA	3.00
E3-LD-060	20	50	7.08	11/1/10 8:00	11/1/10 8:00	NA	dark red	50.3	NA	NA	NA	8.39	NA	3.11

Table A.40. Datasheet for Column E3 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
E3-LD-080	20	50	7.08	11/1/10 8:20	11/1/10 8:20	NA	dark red	49.8	NA	NA	NA	8.41	NA	3.24
E3-LD-120	20	50	7.08	11/1/10 9:02	11/1/10 9:02	NA	dark red	49.4	NA	NA	NA	8.44	NA	3.09
E3-LD-180	20	50	7.08	11/1/10 10:00	11/1/10 10:00	NA	dark red	50.1	NA	NA	NA	8.51	NA	3.05
E3-LD-240	20	50	7.08	11/1/10 11:00	11/1/10 11:00	NA	almost black	50.3	NA	NA	NA	8.46	NA	3.29
E3-LD-600	20	50	7.08	11/1/10 17:00	11/1/10 17:00	NA	almost black	49.8	NA	NA	NA	8.51	NA	3.27
E3-FD-CP	20	50	0.09	11/1/10 17:13	11/1/10 19:43	1.1	almost black	48.3	8.47	23.48	15.01	NA	NA	NA
E3-FDI-CP	20	25	0.09	11/1/10 20:17	11/1/10 22:47	1.0	very dark red	26.1	8.51	20.67	12.16	NA	NA	NA
E3-AN-CP	20	25	0.09	11/1/10 23:00	11/2/10 00:00	0.9	very dark red	24.7	8.54	13.33	4.79	NA	NA	NA

Table A.41. Datasheet for Column E3 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
Elution (EL) Phase Start Date/Time:				11/2/10 7:00										
E3-EL-CP	60	25	0.08	11/2/10 7:00	11/2/10 17:00	1.0	orange	26.4	14.92	57.73	42.81	8.50	14.95	6.45
E3-EDI-CP	20	25	0.09	11/2/10 17:30	11/210 18:30	NA	orange	24.1	8.44	13.14	4.70	NA	NA	NA
E3-RG-CP	20	25	0.09	11/2/10 18:40	11/2/10 21:10	1.2	dark red	25.7	8.49	20.14	11.65	NA	NA	NA

Table A.42. Datasheet for Column E4 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
E4-LD-0	20	50	NA	11/3/10 6:48	11/3/10 6:48	1.2	dark red	53.3	NA	NA	NA	8.44	NA	3.39
Loading (LD) Phase Start Date/Time:				11/3/10 6:55										
E4-LD-006	20	50	10.62	11/3/10 7:01	11/3/10 7:01	NA	dark red	51.6	NA	NA	NA	8.51	NA	3.11
E4-LD-012	20	50	10.62	11/3/10 7:07	11/3/10 7:07	NA	dark red	50.2	NA	NA	NA	8.61	NA	3.32
E4-LD-018	20	50	10.62	11/3/10 7:13	11/3/10 7:13	NA	dark red	49.7	NA	NA	NA	8.42	NA	3.22
E4-LD-024	20	50	10.62	11/3/10 7:19	11/3/10 7:19	NA	dark red	49.8	NA	NA	NA	8.50	NA	3.35
E4-LD-036	20	50	10.62	11/3/10 7:31	11/3/10 7:31	NA	dark red	49.9	NA	NA	NA	8.50	NA	3.26
E4-LD-048	20	50	10.62	11/3/10 7:43	11/3/10 7:43	NA	dark red	50.0	NA	NA	NA	8.59	NA	3.25
E4-LD-060	20	50	10.62	11/3/10 7:55	11/3/10 7:55	NA	dark red	50.1	NA	NA	NA	8.48	NA	3.26
E4-LD-080	20	50	10.62	11/310 8:15	11/310 8:15	NA	dark red	50.2	NA	NA	NA	8.45	NA	3.17
E4-LD-120	20	50	10.62	11/3/10 8:55	11/3/10 8:55	NA	dark red	50.3	NA	NA	NA	8.51	NA	3.31
E4-LD-180	20	50	10.62	11/3/10 9:55	11/3/10 9:55	NA	almost black	50.0	NA	NA	NA	8.56	NA	3.16
E4-LD-240	20	50	10.62	11/3/10 10:55	11/3/10 10:55	NA	almost black	50.3	NA	NA	NA	8.56	NA	3.12
E4-LD-600	20	50	10.62	11/3/10 16:55	11/3/10 16:55	1.3	almost black	50.0	NA	NA	NA	8.41	NA	3.31
E4-FD-CP	20	50	0.09	11/3/10 17:05	11/3/10 19:35	1.2	almost black	48.8	8.31	22.37	14.06	NA	NA	NA

Table A.43. Datasheet for Column E4B Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
E4B-LD-0	20	50	NA	11/8/10 8:25	11/8/10 8:25	1.2	dark red	50.6	NA	NA	NA	8.53	NA	3.37
Loading (LD) Phase Start Date/Time:				11/8/10 8:30										
E4B-LD-004	20	50	0.08	11/8/10 12:30	11/8/10 12:30	NA	dark red	50.2	NA	NA	NA	8.47	NA	3.21
E4B-LD-008	20	50	0.08	11/8/10 16:30	11/8/10 16:30	NA	dark red	50.3	NA	NA	NA	8.43	NA	3.53
E4B-LD-012	20	50	0.08	11/8/10 20:30	11/8/10 20:30	NA	dark red	50.0	NA	NA	NA	8.45	NA	3.04
E4B-LD-024	20	50	0.08	11/9/10 8:30	11/9/10 8:30	NA	dark red	49.8	NA	NA	NA	8.53	NA	2.77
E4B-LD-072	20	50	0.08	11/11/10 8:30	11/11/10 8:30	NA	almost black	50.2	NA	NA	NA	8.54	NA	3.40
E4B-LD-120	20	50	0.08	11/13/10 8:30	11/13/10 8:30	NA	almost black	50.4	NA	NA	NA	8.55	NA	3.24
E4B-LD-168	20	50	0.08	11/15/10 8:30	11/15/10 8:30	NA	almost black	50.3	NA	NA	NA	8.40	NA	3.03
E4B-LD-336	20	50	0.08	11/22/10 8:30	11/22/10 8:30	NA	almost black	50.2	NA	NA	NA	8.55	NA	3.43
E4B-LD-504	20	50	0.08	11/29/10 8:31	11/29/10 8:31	NA	almost black	49.8	NA	NA	NA	8.52	NA	3.55
E4B-LD-672	20	50	0.08	12/6/10 8:31	12/6/10 8:31	NA	almost black	49.3	NA	NA	NA	8.58	NA	3.39
E4B-LD-720	20	50	0.08	12/8/10 8:30	12/8/10 8:30	1.4	almost black	50.2	NA	NA	NA	8.48	NA	3.37
E4B-FD-CP	20	50	0.09	12/8/10 11:17	12/8/10 13:17	1.4	almost black	50.1	8.51	21.67	13.16	NA	NA	NA
E4B-FDI-CP	20	25	0.09	12/8/10 14:25	12/8/10 16:55	1.4	almost black	24.8	8.59	19.87	11.28	NA	NA	NA
E4BAN-CP	20	25	0.09	12/8/10 17:06	12/8/10 18:06	1.4	almost black	24.0	8.50	13.20	4.70	NA	NA	NA

Table A.44. Datasheet for Column E4B Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				12/9/10 6:50										
E4B-EL-CP	60	25	0.08	12/9/10 6:50	12/9/10 16:51	1.2	orange	28.7	14.90	57.84	42.94	8.40	16.34	7.94
E4B-EDI-CP	20	25	0.08	12/9/10 17:08	12/9/10 18:08	1.1	orange	26.0	8.42	12.62	4.20	NA	NA	NA
E4B-RG-CP	20	25	0.09	12/9/10 18:20	12/9/10 20:20	1.3	dark red	26.5	8.51	20.32	11.81	NA	NA	NA

Table A.45. Datasheet for Column E5 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
E5-LD-0	20	50	NA	1/4/11 6:54	1/4/11 6:54	1.9	dark brown	50	NA	NA	NA	8.53	11.61	3.08
Loading (LD) Phase Start Date/Time:				1/4/11 7:00										
E5-LD-006	20	50	10.62	1/4/11 7:06	1/4/11 7:06	NA	dark brown	45.5	NA	NA	NA	8.53	11.39	2.86
E5-LD-012	20	50	10.62	1/4/11 7:12	1/4/11 7:12	NA	dark brown	45.4	NA	NA	NA	8.50	11.42	2.92
E5-LD-018	20	50	10.62	1/4/11 7:18	1/4/11 7:18	NA	dark brown	45.6	NA	NA	NA	8.34	11.08	2.74
E5-LD-024	20	50	10.62	1/4/11 7:24	1/4/11 7:24	NA	dark brown	45.9	NA	NA	NA	8.50	11.56	3.06
E5-LD-036	20	50	10.62	1/4/11 7:36	1/4/11 7:36	NA	dark brown	46.2	NA	NA	NA	8.51	11.34	2.83
E5-LD-048	20	50	10.62	1/4/11 7:48	1/4/11 7:48	NA	dark brown	47.3	NA	NA	NA	8.50	11.11	2.61
E5-LD-060	20	50	10.62	1/4/11 8:00	1/4/11 8:00	NA	dark brown	50.5	NA	NA	NA	8.42	11.20	2.78

Table A.45. Datasheet for Column E5 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
E5-LD-080	20	50	10.62	1/4/11 8:20	1/4/11 8:20	NA	dark brown	49.0	NA	NA	NA	8.35	11.28	2.93
E5-LD-120	20	50	10.62	1/4/11 21:15	1/4/11 21:15	NA	dark brown	41.5	NA	NA	NA	8.45	11.96	3.51
E5-LD-180	20	50	10.62	1/4/11 22:15	1/4/11 22:15	NA	dark brown	41.8	NA	NA	NA	8.48	11.67	3.19
E5-LD-240	20	50	10.62	1/4/11 23:15	1/4/11 23:15	NA	dark brown	42.9	NA	NA	NA	8.50	11.96	3.46
E5-LD-600	20	50	10.62	1/5/11 5:15	1/5/11 5:15	NA	dark brown	47.8	NA	NA	NA	8.54	11.41	2.87
E5-LD-900	20	50	10.62	1/5/11 10:15	1/5/11 10:15	NA	dark brown	48.8	NA	NA	NA	8.47	11.47	3.00
E5-LD-1200	20	50	10.62	1/5/11 15:15	1/5/11 15:15	1.9	dark brown	48.4	NA	NA	NA	8.56	11.48	2.92
E5-FD-CP	20	50	0.09	1/5/11 15:25	1/5/11 18:05	NA	dark brown	58.1	8.56	21.73	13.17	NA	NA	NA
E5-FDI-CP	20	25	0.09	1/5/11 18:17	1/5/11 20:47	NA	dark brown	26.8	8.50	21.00	12.50	NA	NA	NA
E5-AN-CP	20	25	0.09	1/5/11 20:55	1/5/11 21:55	NA	dark brown	NA	8.46	13.07	4.61	NA	NA	NA

Table A.46. Datasheet for Column E5 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				1/5/11 22:04										
E5-EL-CP	60	25	0.09	1/5/11 22:04	1/6/11 9:04	1.7	reddish orange	26.2	14.95	55.14	40.19	8.53	18.95	10.42
E5-EDI-CP	20	25	0.09	1/6/11 9:10	1/6/11 10:13	1.6	reddish orange	25.1	8.39	12.47	4.08	NA	NA	NA

Table A.47. Datasheet for Column F1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
F1-PT-DIW1	20	25	0.09	4/25/11 12:16	4/25/11 14:46	1.1	dark red	23.8	8.50	21.49	12.99	NA	NA	NA
F1-PT-ACID	20	25	0.09	4/25/11 14:51	4/25/11 18:30	1.0	orange	23.7	8.47	28.02	19.55	NA	NA	NA
F1-PT-DIW2	20	25	0.09	4/25/11 19:20	4/25/11 20:20	1.0	orange	23.4	8.50	13.48	4.98	NA	NA	NA
F1-PT-NaOH	20	25	0.09	4/25/11 20:24	4/25/11 22:24	1.2	dark red	23.2	8.44	18.73	10.29	NA	NA	NA
F1-LD-0	20	55	NA	4/26/11 6:50	4/26/11 6:50	1.2	dark red	56.9	NA	NA	NA	8.50	15.67	7.17
Loading (LD) Phase Start Date/Time:				4/26/11 6:55										
F1-LD-006	20	55	10.62	4/26/11 7:01	4/26/11 7:01	NA	dark red	52.9	NA	NA	NA	8.54	15.63	7.09
F1-LD-012	20	55	10.62	4/26/11 7:07	4/26/11 7:07	NA	dark red	51.0	NA	NA	NA	8.35	14.75	6.40
F1-LD-018	20	55	10.62	4/26/11 7:13	4/26/11 7:13	NA	dark red	50.3	NA	NA	NA	8.39	14.98	6.59
F1-LD-024	20	55	10.62	4/26/11 7:19	4/26/11 7:19	NA	dark red	50.4	NA	NA	NA	8.58	15.06	6.48
F1-LD-036	20	55	10.62	4/26/11 7:31	4/26/11 7:31	NA	dark red	51.4	NA	NA	NA	8.56	15.20	6.64
F1-LD-048	20	55	10.62	4/26/11 7:43	4/26/11 7:43	NA	dark red	52.0	NA	NA	NA	8.40	14.78	6.38
F1-LD-060	20	55	10.62	4/26/11 7:57	4/26/11 7:57	NA	dark red	52.9	NA	NA	NA	8.53	14.72	6.19
F1-LD-080	20	55	10.62	4/26/11 8:15	4/26/11 8:15	NA	dark red	53.6	NA	NA	NA	8.53	15.35	6.82
F1-LD-120	20	55	10.62	4/26/11 8:55	4/26/11 8:55	NA	dark red	54.4	NA	NA	NA	8.53	15.24	6.71
F1-LD-180	20	55	10.62	4/26/11 9:55	4/26/11 9:55	NA	dark red	54.8	NA	NA	NA	8.51	15.42	6.91

Table A.47. Datasheet for Column F1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
F1-LD-240	20	55	10.62	4/26/11 10:55	4/26/11 10:55	NA	dark red	54.8	NA	NA	NA	8.49	16.67	8.18
F1-LD-600	20	55	10.62	4/26/11 16:55	4/26/11 16:55	NA	dark red	54.9	NA	NA	NA	8.44	13.60	5.16
F1-FD-CP	20	55	0.09	4/26/11 17:11	4/26/11 19:43	NA	dark red	56.0	8.53	23.03	14.50	NA	NA	NA
F1-FDI-CP	20	25	0.09	4/26/11 20:13	4/26/11 23:02	1.2	dark red	24	8.44	20.53	12.09	NA	NA	NA
F1-AN-CP	20	25	0.09	4/26/11 23:09	4/27/11 00:09	1.2	dark red	24	8.42	13.61	5.19	NA	NA	NA

Table A.48. Datasheet for Column F1 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				4/27/11 6:47										
F1-EL-CP	60	25	0.08	4/27/11 6:47	4/27/11 17:47	1.0	orange	23.9	14.94	66.21	51.27	8.42	15.49	7.07
F1-EDI-CP	20	25	0.09	4/27/11 17:59	4/27/11 18:59	1.0	orange	23.6	8.46	13.37	4.91	NA	NA	NA
F1-RG-CP	20	25	0.09	4/27/11 19:04	4/27/11 20:34	1.2	dark red	23.7	8.48	26.00	17.52	NA	NA	NA

Table A.49. Datasheet for Column F2 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
F2-LD-0	20	55	NA	5/11/11 6:34	5/11/11 6:34	1.1	dark red	55.7	NA	NA	NA	8.49	NA	3.96

Table A.49. Datasheet for Column F2 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
Loading (LD) Phase Start Date/Time:				5/11/11 6:53										
F2-LD-006	20	55	10.62	5/11/11 6:59	5/11/11 6:59	NA	dark red	53.5	NA	NA	NA	8.61	NA	3.55
F2-LD-012	20	55	10.62	5/11/11 7:05	5/11/11 7:05	NA	dark red	52.9	NA	NA	NA	8.51	NA	3.17
F2-LD-018	20	55	10.62	5/11/11 7:11	5/11/11 7:11	NA	dark red	52.8	NA	NA	NA	8.47	NA	3.22
F2-LD-024	20	55	10.62	5/11/11 7:17	5/11/11 7:17	NA	dark red	52.8	NA	NA	NA	8.38	NA	3.41
F2-LD-036	20	55	10.62	5/11/11 7:31	5/11/11 7:31	NA	dark red	54.1	NA	NA	NA	8.52	NA	3.37
F2-LD-048	20	55	10.62	5/11/11 7:41	5/11/11 7:41	NA	dark red	53.9	NA	NA	NA	8.47	NA	3.43
F2-LD-060	20	55	10.62	5/11/11 7:53	5/11/11 7:53	NA	dark red	54.2	NA	NA	NA	8.45	NA	3.38
F2-LD-080	20	55	10.62	5/11/11 8:13	5/11/11 8:13	NA	dark red	54.6	NA	NA	NA	8.52	NA	3.24
F2-LD-120	20	55	10.62	5/11/11 8:53	5/11/11 8:53	NA	dark red	55.1	NA	NA	NA	8.47	NA	3.20
F2-LD-180	20	55	10.62	5/11/11 9:58	5/11/11 9:58	NA	dark red	54.5	NA	NA	NA	8.43	NA	3.65
F2-LD-240	20	55	10.62	5/11/11 10:53	5/11/11 10:53	NA	dark red	54.5	NA	NA	NA	8.49	NA	2.98
F2-LD-600	20	55	10.62	5/11/11 16:53	5/11/11 16:53	1.2	dark red	55.0	NA	NA	NA	8.46	NA	4.02
F2-FD-CP	20	55	0.09	5/11/11 17:17	5/11/11 19:47	1.2	dark red	54.2	8.57	24.72	16.15	NA	NA	NA
F2-FDI-CP	20	25	0.09	5/11/11 20:09	5/11/11 22:39	1.2	dark red	25.3	8.49	21.75	13.26	NA	NA	NA
F2-AN-CP	20	25	0.09	5/11/11 22:46	5/11/11 23:46	1.2	dark red	25.3	8.40	13.66	5.26	NA	NA	NA

Table A.50. Datasheet for Column F2 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
Elution (EL) Phase Start Date/Time:				5/12/11 6:40										
F2-EL-CP	60	25	0.09	5/12/11 6:40	5/12/11 18:40	1.2	orange	RT	14.91	71.44	56.53	8.49	18.39	9.90
F2-EDI-CP	20	25	0.09	5/12/11 19:05	5/12/11 20:05	1.2	orange	RT	8.51	13.60	5.09	NA	NA	NA
F2-RG-CP	20	25	0.10	5/12/11 20:10	5/12/11 22:40	1.2	dark red	RT	8.50	24.04	15.54	NA	NA	NA

Table A.51. Datasheet for Column F3 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
F3-LD-0	20	55	NA	5/17/11 6:42	5/17/11 6:42	1.1	dark red	60.0	NA	NA	NA	8.46	NA	3.82
Loading (LD) Phase Start Date/Time:				5/17/11 6:48										
F3-LD-006	20	55	7.08	5/17/11 6:54	5/17/11 6:54	NA	almost black	55.6	NA	NA	NA	8.52	NA	4.12
F3-LD-012	20	55	7.08	5/17/11 7:00	5/17/11 7:00	NA	almost black	53.3	NA	NA	NA	8.53	NA	3.70
F3-LD-018	20	55	7.08	5/17/11 7:06	5/17/11 7:06	NA	almost black	52.2	NA	NA	NA	8.44	NA	4.03
F3-LD-024	20	55	7.08	5/17/11 7:12	5/17/11 7:12	NA	almost black	52.1	NA	NA	NA	8.46	NA	4.02
F3-LD-036	20	55	7.08	5/17/11 7:24	5/17/11 7:24	NA	almost black	53.0	NA	NA	NA	8.52	NA	3.84
F3-LD-048	20	55	7.08	5/17/11 7:36	5/17/11 7:36	NA	almost black	53.9	NA	NA	NA	8.61	NA	3.71
F3-LD-060	20	55	7.08	5/17/11 7:48	5/17/11 7:48	NA	almost black	54.6	NA	NA	NA	8.59	NA	3.93
F3-LD-080	20	55	7.08	5/17/11 8:08	5/17/11 8:08	NA	almost black	55.2	NA	NA	NA	8.58	NA	3.86

Table A.51. Datasheet for Column F3 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
F3-LD-120	20	55	7.08	5/17/11 8:58	5/17/11 8:58	NA	almost black	55.3	NA	NA	NA	8.49	NA	3.99
F3-LD-180	20	55	7.08	5/17/11 9:48	5/17/11 9:48	NA	almost black	55.3	NA	NA	NA	8.43	NA	4.08
F3-LD-240	20	55	7.08	5/17/11 10:48	5/17/11 10:48	NA	almost black	55.2	NA	NA	NA	8.52	NA	3.74
F3-LD-600	20	55	7.08	5/17/11 16:48	5/17/11 16:48	NA	almost black	54.7	NA	NA	NA	8.48	NA	4.19
F3-FD-CP	20	55	0.08	5/17/11 17:06	5/17/11 19:36	NA	almost black	53.5	8.49	22.86	14.37	NA	NA	NA
F3-FDI-CP	20	25	0.08	5/17/11 20:03	5/17/11 22:33	NA	almost black	23.2	8.54	20.48	11.94	NA	NA	NA
F3-AN-CP	20	25	0.08	5/17/11 22:37	5/17/11 23:37	1.1	almost black	23.4	8.44	13.29	4.85	NA	NA	NA

Table A.52. Datasheet for Column F3 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				5/18/11 6:50										
F3-EL-CP	60	25	0.08	5/18/11 6:50	5/18/11 18:50	0.8	orange	25.2	14.83	70.55	55.72	8.50	17.61	9.11
F3-EDI-CP	20	25	0.09	5/18/11 19:03	5/18/11 20:03	0.8	orange	RT	8.39	13.38	4.99	NA	NA	NA
F3-RG-CP	20	25	0.10	5/18/11 20:12	5/18/11 22:42	1.3	dark red	25.6	8.56	23.54	14.98	NA	NA	NA

Table A.53. Datasheet for Column F4 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
F4-LD-0	20	55	NA	5/25/11 6:51	5/25/11 6:51	1.2	dark red	63.5	NA	NA	NA	8.59	NA	3.40
Loading (LD) Phase Start Date/Time:				5/25/11 6:58										
F4-LD-006	20	55	10.62	5/25/11 7:04	5/25/11 7:04	NA	dark red	57.8	NA	NA	NA	8.43	NA	3.20
F4-LD-012	20	55	10.62	5/25/11 7:10	5/25/11 7:10	NA	dark red	54.8	NA	NA	NA	8.58	NA	3.61
F4-LD-018	20	55	10.62	5/25/11 7:16	5/25/11 7:16	NA	dark red	52.7	NA	NA	NA	8.57	NA	3.60
F4-LD-024	20	55	10.62	5/25/11 7:22	5/25/11 7:22	NA	dark red	52.0	NA	NA	NA	8.56	NA	3.31
F4-LD-036	20	55	10.62	5/25/11 7:34	5/25/11 7:34	NA	dark red	52.5	NA	NA	NA	8.50	NA	3.34
F4-LD-048	20	55	10.62	5/25/11 7:46	5/25/11 7:46	NA	dark red	53.3	NA	NA	NA	8.55	NA	3.59
F4-LD-060	20	55	10.62	5/25/11 7:58	5/25/11 7:58	NA	dark red	53.7	NA	NA	NA	8.50	NA	3.59
F4-LD-080	20	55	10.62	5/25/11 8:18	5/25/11 8:18	NA	dark red	53.9	NA	NA	NA	8.46	NA	3.56
F4-LD-120	20	55	10.62	5/25/11 8:58	5/25/11 8:58	NA	dark red	54.3	NA	NA	NA	8.49	NA	3.48
F4-LD-180	20	55	10.62	5/25/11 9:58	5/25/11 9:58	NA	dark red	54.5	NA	NA	NA	8.54	NA	3.58
F4-LD-240	20	55	10.62	5/25/11 10:58	5/25/11 10:58	NA	dark red	54.2	NA	NA	NA	8.40	NA	3.62
F4-LD-600	20	55	10.62	5/25/11 16:58	5/25/11 16:58	1.2	dark red	54.9	NA	NA	NA	8.54	NA	3.73
F4-FD-CP	20	55	0.09	5/25/11 17:16	5/25/11 19:46	1.2	dark red	55.2	8.55	23.31	14.76	NA	NA	NA
F4-FDI-CP	20	25	0.09	5/25/11 20:19	5/25/11 22:49	1.2	dark red	25	8.46	21.40	12.94	NA	NA	NA

Table A.54. Datasheet for Column F4B Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
F4B-LD-0	20	55	NA	6/8/11 8:28	6/8/11 8:28	1.1	almost black	61.6	NA	NA	NA	8.56	NA	2.89
Loading (LD) Phase Start Date/Time:				6/8/11 8:33										
F4B-LD-004	20	55	0.08	6/8/11 12:33	6/8/11 12:33	NA	almost black	57.7	NA	NA	NA	8.52	NA	3.31
F4B-LD-008	20	55	0.08	6/8/11 16:33	6/8/11 16:33	NA	almost black	55.1	NA	NA	NA	8.45	NA	3.88
F4B-LD-012	20	55	0.08	6/8/11 20:33	6/8/11 20:33	NA	almost black	55.5	NA	NA	NA	8.56	NA	3.72
F4B-LD-024	20	55	0.08	6/9/11 8:33	6/9/11 8:33	NA	almost black	55.7	NA	NA	NA	8.40	NA	3.74
F4B-LD-072	20	55	0.08	6/11/11 8:33	6/11/11 8:33	NA	almost black	55.4	NA	NA	NA	8.47	NA	3.67
F4B-LD-120	20	55	0.08	6/13/11 8:34	6/13/11 8:34	NA	almost black	55.3	NA	NA	NA	8.54	NA	3.85
F4B-LD-168	20	55	0.08	6/15/11 8:33	6/15/11 8:33	NA	almost black	56.0	NA	NA	NA	8.54	NA	3.59
F4B-LD-336	20	55	0.08	6/22/11 8:30	6/22/11 8:30	NA	almost black	55.1	NA	NA	NA	8.47	NA	2.80
F4B-LD-504	20	55	0.08	6/29/11 8:30	6/29/11 8:30	NA	almost black	55.6	NA	NA	NA	8.46	NA	3.74
F4B-FD-CP	20	55	0.09	7/1/11 14:25	7/1/11 16:55	1.7	black	55.4	8.59	25.06	16.47	NA	NA	NA
F4B-FDI-CP	20	25	0.09	7/1/11 17:08	7/1/11 19:38	1.7	black	25.1	8.36	21.54	13.18	NA	NA	NA
F4B-AN-CP	20	25	0.09	7/5/11 9:45	7/5/11 10:45	1.6	reddish brown	25.3	8.57	14.08	5.51	NA	NA	NA

Table A.55. Datasheet for Column F4B Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
Elution (EL) Phase Start Date/Time:				7/6/11 6:37										
F4B-EL-CP	60	25	0.08	7/6/11 6:37	7/6/11 16:37	1.3	brownish red	RT	14.92	60.55	45.63	8.37	15.99	7.62
F4B-EDI-CP	20	25	0.08	7/6/11 16:52	7/6/11 17:52	1.3	brownish red	RT	8.46	12.93	4.47	NA	NA	NA
F4B-RG-CP	20	25	0.09	7/6/11 18:03	7/6/11 20:03	1.7	brownish red	RT	8.40	21.25	12.85	NA	NA	NA

Table A.56. Datasheet for Column F5 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
F5-LD-0	20	55	NA	7/7/11 6:37	7/7/11 6:37	1. 5	brownish red	59.9	NA	NA	NA	8.53	12.07	3.54
Loading (LD) Phase Start Date/Time:				7/7/11 6:48										
F5-LD-006	20	55	10.62	7/7/11 6:54	7/7/11 6:54	NA	brownish red	54.2	NA	NA	NA	8.39	11.79	3.40
F5-LD-012	20	55	10.62	7/7/11 7:00	7/7/11 7:00	NA	brownish red	51.8	NA	NA	NA	8.60	12.25	3.65
F5-LD-018	20	55	10.62	7/7/11 7:06	7/7/11 7:06	NA	brownish red	50.7	NA	NA	NA	8.64	12.16	3.52
F5-LD-024	20	55	10.62	7/7/11 7:12	7/7/11 7:12	NA	brownish red	50.3	NA	NA	NA	8.46	12.12	3.66
F5-LD-036	20	55	10.62	7/7/11 7:24	7/7/11 7:24	NA	brownish red	51.5	NA	NA	NA	8.54	11.90	3.36
F5-LD-048	20	55	10.62	7/7/11 7:36	7/7/11 7:36	NA	brownish red	52.3	NA	NA	NA	8.57	12.02	3.45
F5-LD-060	20	55	10.62	7/7/11 7:48	7/7/11 7:48	NA	dark brown	52.9	NA	NA	NA	8.43	11.95	3.52

Table A.56. Datasheet for Column F5 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
F5-LD-080	20	55	10.62	7/7/11 8:08	7/7/11 8:08	NA	dark brown	53.0	NA	NA	NA	8.58	12.13	3.55
F5-LD-120	20	55	10.62	7/7/11 8:48	7/7/11 8:48	NA	dark brown	53.3	NA	NA	NA	8.39	11.79	3.40
F5-LD-180	20	55	10.62	7/7/11 9:48	7/7/11 9:48	NA	dark brown	53.6	NA	NA	NA	8.68	12.03	3.35
F5-LD-240	20	55	10.62	7/7/11 10:48	7/7/11 10:48	NA	dark brown	54.5	NA	NA	NA	8.57	12.03	3.46
F5-LD-600	20	55	10.62	7/7/11 16:48	7/7/11 16:48	NA	dark brown	55.1	NA	NA	NA	8.52	12.71	4.19
F5-FD-CP	20	55	0.09	7/7/11 17:10	7/7/11 19:40	NA	dark brown	NA	8.61	23.68	15.07	NA	NA	NA
F5-FDI-CP	20	25	0.09	7/7/11 19:58	7/7/11 22:28	NA	dark brown	NA	8.48	21.17	12.69	NA	NA	NA
F5-AN-CP	20	25	0.09	7/7/11 22:32	7/7/11 23:32	NA	dark brown	NA	8.60	13.70	5.10	NA	NA	NA

Table A.57. Datasheet for Column F5 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
Elution (EL) Phase Start Date/Time:				7/11/11 6:40										
F5-EL-CP	60	25	0.08	7/11/11 6:40	7/11/11 16:40	1.1	orange red	RT	14.87	60.68	45.81	8.53	19.69	11.16
F5-EDI-CP	20	25	0.08	7/11/11 16:48	7/11/11 17:48	1.1	orange red	RT	8.48	13.09	4.61	NA	NA	NA

Table A.58. Datasheet for Column G1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
G1-PT-DIW1	20	25	0.09	4/25/11 12:16	4/25/11 14:46	1.1	dark red	23.4	8.53	19.65	11.12	NA	NA	NA
G1-PT-ACID	20	25	0.09	4/25/11 14:51	4/25/11 19:01	1.0	orange	23.7	NA	NA	35.91	NA	NA	NA
G1-PT-DIW2	20	25	0.09	4/25/11 19:20	4/25/11 20:20	1.0	orange	23.2	8.47	13.12	4.65	NA	NA	NA
G1-PT-NaOH	20	25	0.09	4/25/11 20:24	4/25/11 22:34	1.3	dark red	23.1	8.57	19.08	10.51	NA	NA	NA
G1-LD-0	20	60	NA	4/26/11 6:53	4/26/11 6:53	1.3	dark red	60.1	NA	NA	NA	8.54	15.29	6.75
Loading (LD) Phase Start Date/Time:				4/26/11 6:58										
G1-LD-006	20	60	10.62	4/26/11 7:04	4/26/11 7:04	NA	dark red	55.5	NA	NA	NA	8.55	14.63	6.08
G1-LD-012	20	60	10.62	4/26/11 7:10	4/26/11 7:10	NA	dark red	53.2	NA	NA	NA	8.47	13.92	5.45
G1-LD-018	20	60	10.62	4/26/11 7:16	4/26/11 7:16	NA	dark red	52.5	NA	NA	NA	8.50	15.02	6.52
G1-LD-024	20	60	10.62	4/26/11 7:22	4/26/11 7:22	NA	dark red	52.5	NA	NA	NA	8.50	14.97	6.47
G1-LD-036	20	60	10.62	4/26/11 7:34	4/26/11 7:34	NA	dark red	53.0	NA	NA	NA	8.50	14.81	6.31
G1-LD-048	20	60	10.62	4/26/11 7:46	4/26/11 7:46	NA	dark red	53.3	NA	NA	NA	8.53	15.07	6.54
G1-LD-060	20	60	10.62	4/26/11 7:58	4/26/11 7:58	NA	dark red	54.0	NA	NA	NA	8.48	15.10	6.62
G1-LD-080	20	60	10.62	4/26/11 8:18	4/26/11 8:18	NA	dark red	54.5	NA	NA	NA	8.55	14.15	5.60
G1-LD-120	20	60	10.62	4/26/11 8:58	4/26/11 8:58	NA	dark red	55.3	NA	NA	NA	8.51	14.43	5.92
G1-LD-180	20	60	10.62	4/26/11 9:58	4/26/11 9:58	NA	dark red	57.1	NA	NA	NA	8.49	14.05	5.56
G1-LD-240	20	60	10.62	4/26/11 10:58	4/26/11 10:58	NA	dark red	57.4	NA	NA	NA	8.54	15.62	7.08

Table A.58. Datasheet for Column G1 Pretreatment, Loading, and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
G1-LD-600	20	60	10.62	4/26/11 16:58	4/26/11 16:58	NA	dark red	59.7	NA	NA	NA	8.48	12.98	4.50
G1-FD-CP	20	60	0.09	4/26/11 17:11	4/26/11 19:43	NA	dark red	59.9	8.46	24.85	16.39	NA	NA	NA
G1-FDI-CP	20	25	0.09	4/26/11 20:13	4/26/11 23:02	1.3	dark red	24	8.54	18.36	9.82	NA	NA	NA
G1-AN-CP	20	25	0.09	4/26/11 23:09	4/27/11 00:09	1.3	dark red	24	8.51	13.24	4.73	NA	NA	NA

Table A.59. Datasheet for Column G1 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
Elution (EL) Phase Start Date/Time:				4/27/11 6:47										
G1-EL-CP	60	25	0.08	4/27/11 6:47	4/27/11 17:47	0.9	orange	25	14.96	61.72	46.76	8.50	16.38	7.88
G1-EDI-CP	20	25	0.09	4/27/11 17:59	4/27/11 18:59	0.9	orange	25.0	8.56	13.22	4.66	NA	NA	NA
G1-RG-CP	20	25	0.20	4/27/11 19:04	4/27/11 20:34	1.3	dark red	25.7	8.40	24.35	15.95	NA	NA	NA

Table A.60. Datasheet for Column G2 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
G2-LD-0	20	60	NA	5/11/11 6:36	5/11/11 6:36	1.2	dark red	60.4	NA	NA	NA	8.48	NA	4.10
Loading (LD) Phase Start Date/Time:				5/11/11 6:50										
G2-LD-006	20	60	10.62	5/11/11 6:56	5/11/11 6:56	NA	dark red	57.6	NA	NA	NA	8.56	NA	3.08

Table A.60. Datasheet for Column G2 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
G2-LD-012	20	60	10.62	5/11/11 7:02	5/11/11 7:02	NA	dark red	56.8	NA	NA	NA	8.49	NA	3.37
G2-LD-018	20	60	10.62	5/11/11 7:08	5/11/11 7:08	NA	dark red	56.3	NA	NA	NA	8.50	NA	2.86
G2-LD-024	20	60	10.62	5/11/11 7:14	5/11/11 7:14	NA	dark red	56.1	NA	NA	NA	8.58	NA	3.27
G2-LD-036	20	60	10.62	5/11/11 7:27	5/11/11 7:27	NA	dark red	56.0	NA	NA	NA	8.42	NA	3.42
G2-LD-048	20	60	10.62	5/11/11 7:38	5/11/11 7:38	NA	dark red	56.3	NA	NA	NA	8.48	NA	3.48
G2-LD-060	20	60	10.62	5/11/11 7:51	5/11/11 7:51	NA	dark red	56.9	NA	NA	NA	8.47	NA	3.21
G2-LD-080	20	60	10.62	5/11/11 8:10	5/11/11 8:10	NA	dark red	57.4	NA	NA	NA	8.49	NA	3.05
G2-LD-120	20	60	10.62	5/11/11 8:50	5/11/11 8:50	NA	dark red	57.7	NA	NA	NA	8.49	NA	3.32
G2-LD-180	20	60	10.62	5/11/11 9:57	5/11/11 9:57	NA	dark red	58.2	NA	NA	NA	8.46	NA	3.33
G2-LD-240	20	60	10.62	5/11/11 10:50	5/11/11 10:50	NA	dark red	58.1	NA	NA	NA	8.45	NA	3.37
G2-LD-600	20	60	10.62	5/11/11 16:50	5/11/11 16:50	NA	dark red	59.4	NA	NA	NA	8.56	NA	3.69
G2-FD-CP	20	60	0.09	5/11/11 17:17	5/11/11 19:47	1.2	dark red	61.3	8.48	22.63	14.15	NA	NA	NA
G2-FDI-CP	20	25	0.09	5/11/11 20:09	5/11/11 22:39	1.2	dark red	25.3	8.43	19.93	11.50	NA	NA	NA
G2-AN-CP	20	25	0.09	5/11/11 22:46	5/11/11 23:46	1.2	dark red	25.3	8.52	13.17	4.65	NA	NA	NA

Table A.61. Datasheet for Column G2 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				5/12/11 6:40										
G2-EL-CP	60	25	0.08	5/12/11 6:40	5/12/11 18:40	1.0	orange	RT	14.90	64.92	50.02	8.52	17.84	9.32
G2-EDI-CP	20	25	0.09	5/12/11 19:05	5/12/11 20:05	1.0	orange	RT	8.46	13.02	4.56	NA	NA	NA
G2-RG-CP	20	25	0.10	5/12/11 20:10	5/12/11 22:40	1.2	dark red	RT	8.45	21.95	13.50	NA	NA	NA

Table A.62. Datasheet for Column G3 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
G3-LD-0	20	60	NA	5/17/11 6:40	5/17/11 6:40	1.2	dark red	65.5	NA	NA	NA	8.50	NA	4.55
Loading (LD) Phase Start Date/Time:				5/17/11 6:45										
G3-LD-006	20	60	7.08	5/17/11 6:51	5/17/11 6:51	NA	almost black	60.5	NA	NA	NA	8.48	NA	3.79
G3-LD-012	20	60	7.08	5/17/11 6:57	5/17/11 6:57	NA	almost black	57.8	NA	NA	NA	8.48	NA	3.94
G3-LD-018	20	60	7.08	5/17/11 7:03	5/17/11 7:03	NA	almost black	56.3	NA	NA	NA	8.46	NA	4.01
G3-LD-024	20	60	7.08	5/17/11 7:09	5/17/11 7:09	NA	almost black	55.9	NA	NA	NA	8.40	NA	3.87
G3-LD-036	20	60	7.08	5/17/11 7:21	5/17/11 7:21	NA	almost black	56.6	NA	NA	NA	8.56	NA	3.79
G3-LD-048	20	60	7.08	5/17/11 7:33	5/17/11 7:33	NA	almost black	57.5	NA	NA	NA	8.48	NA	3.44
G3-LD-060	20	60	7.08	5/17/11 7:45	5/17/11 7:45	NA	almost black	58.4	NA	NA	NA	8.48	NA	3.75
G3-LD-080	20	60	7.08	5/17/11 8:05	5/17/11 8:05	NA	almost black	59.6	NA	NA	NA	8.47	NA	3.62

Table A.62. Datasheet for Column G3 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
G3-LD-120	20	60	7.08	5/17/11 8:57	5/17/11 8:57	NA	almost black	60.4	NA	NA	NA	8.51	NA	3.62
G3-LD-180	20	60	7.08	5/17/11 9:45	5/17/11 9:45	NA	almost black	60.9	NA	NA	NA	8.52	NA	3.72
G3-LD-240	20	60	7.08	5/17/11 10:45	5/17/11 10:45	NA	almost black	60.3	NA	NA	NA	8.55	NA	3.87
G3-LD-600	20	60	7.08	5/17/11 16:45	5/17/11 16:45	NA	almost black	59.6	NA	NA	NA	8.41	NA	3.39
G3-FD-CP	20	60	0.08	5/17/11 17:06	5/17/11 19:36	NA	almost black	61.8	8.46	21.42	12.96	NA	NA	NA
G3-FDI-CP	20	25	0.08	5/17/11 20:03	5/17/11 22:33	NA	almost black	21.8	8.51	18.94	10.43	NA	NA	NA
G3-AN-CP	20	25	0.08	5/17/11 22:37	5/17/11 23:37	1.2	almost black	22.4	8.52	12.75	4.23	NA	NA	NA

Table A.63. Datasheet for Column G3 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Gross	Net	Sample Vial Weight, g Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				5/18/11 6:50										
G3-EL-CP	60	25	0.08	5/18/11 6:50	5/18/11 18:50	1.1	orange	25.8	14.93	65.12	50.19	8.52	16.07	7.55
G3-EDI-CP	20	25	0.09	5/18/11 19:03	5/18/11 20:03	1.1	orange	RT	8.43	13.01	4.58	NA	NA	NA
G3-RG-CP	20	25	0.10	5/18/11 20:12	5/18/11 22:42	1.4	dark red	24.9	8.51	21.82	13.31	NA	NA	NA

Table A.64. Datasheet for Column G4 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
G4-LD-0	20	60	NA	5/25/11 6:50	5/25/11 6:50	1.3	dark red	66.9	NA	NA	NA	8.53	NA	3.43
Loading (LD) Phase Start Date/Time:				5/25/11 6:55										
G4-LD-006	20	60	10.62	5/25/11 7:01	5/25/11 7:01	NA	dark red	61.0	NA	NA	NA	8.45	NA	3.83
G4-LD-012	20	60	10.62	5/25/11 7:07	5/25/11 7:07	NA	dark red	58.9	NA	NA	NA	8.48	NA	3.55
G4-LD-018	20	60	10.62	5/25/11 7:13	5/25/11 7:13	NA	dark red	58.1	NA	NA	NA	8.58	NA	3.61
G4-LD-024	20	60	10.62	5/25/11 7:19	5/25/11 7:19	NA	dark red	58.0	NA	NA	NA	8.43	NA	3.05
G4-LD-036	20	60	10.62	5/25/11 7:31	5/25/11 7:31	NA	dark red	58.6	NA	NA	NA	8.52	NA	3.52
G4-LD-048	20	60	10.62	5/25/11 7:43	5/25/11 7:43	NA	dark red	59.2	NA	NA	NA	8.53	NA	3.27
G4-LD-060	20	60	10.62	5/25/11 7:55	5/25/11 7:55	NA	dark red	59.5	NA	NA	NA	8.58	NA	3.19
G4-LD-080	20	60	10.62	5/25/11 8:15	5/25/11 8:15	NA	dark red	59.6	NA	NA	NA	8.42	NA	3.30
G4-LD-120	20	60	10.62	5/25/11 8:55	5/25/11 8:55	NA	dark red	59.8	NA	NA	NA	8.55	NA	3.11
G4-LD-180	20	60	10.62	5/25/11 9:55	5/25/11 9:55	NA	dark red	59.6	NA	NA	NA	8.42	NA	3.34
G4-LD-240	20	60	10.62	5/25/11 10:55	5/25/11 10:55	NA	almost black	59.1	NA	NA	NA	8.47	NA	3.47
G4-LD-600	20	60	10.62	5/25/11 16:55	5/25/11 16:55	1.3	almost black	60.1	NA	NA	NA	8.47	NA	3.92
G4-FD-CP	20	60	0.09	5/25/11 17:16	5/25/11 19:46	1.3	almost black	60.3	8.53	22.81	14.28	NA	NA	NA
G4-FDI-CP	20	25	0.09	5/25/11 20:19	5/25/11 22:49	1.3	almost black	25	8.38	20.50	12.12	NA	NA	NA

Table A.65. Datasheet for Column G4B Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g Tare	Effluent Bottle Weight, g Gross	Effluent Bottle Weight, g Net	Sample Vial Weight, g Tare	Sample Vial Weight, g Gross	Sample Vial Weight, g Net
G4B-LD-0	20	60	NA	6/8/11 8:27	6/8/11 8:27	1.3	almost black	66.9	NA	NA	NA	8.53	NA	3.44
Loading (LD) Phase Start Date/Time:				6/8/11 8:30										
G4B-LD-004	20	60	0.08	6/8/11 12:30	6/8/11 12:30	NA	almost black	61.2	NA	NA	NA	8.47	NA	3.59
G4B-LD-008	20	60	0.08	6/8/11 16:30	6/8/11 16:30	NA	almost black	60.0	NA	NA	NA	8.45	NA	3.92
G4B-LD-012	20	60	0.08	6/8/11 20:30	6/8/11 20:30	NA	almost black	60.5	NA	NA	NA	8.45	NA	3.88
G4B-LD-024	20	60	0.08	6/9/11 8:30	6/9/11 8:30	NA	almost black	60.7	NA	NA	NA	8.59	NA	3.92
G4B-LD-072	20	60	0.08	6/11/11 8:30	6/11/11 8:30	NA	almost black	60.2	NA	NA	NA	8.51	NA	3.50
G4B-LD-120	20	60	0.08	6/13/11 8:33	6/13/11 8:33	NA	almost black	60.1	NA	NA	NA	8.42	NA	3.62
G4B-LD-168	20	60	0.08	6/15/11 8:32	6/15/11 8:32	NA	almost black	60.9	NA	NA	NA	8.48	NA	3.28
G4B-LD-336	20	60	0.08	6/22/11 8:31	6/22/11 8:31	NA	almost black	NA	NA	NA	NA	8.47	NA	2.83
G4B-FD-CP	20	60	0.09	7/1/11 13:38	7/1/11 16:08	1.6	black	60.2	8.53	21.75	13.22	NA	NA	NA
G4B-FDI-CP	20	25	0.09	7/1/11 16:10	7/1/11 18:40	1.6	black	23.8	8.54	20.70	12.16	NA	NA	NA
G4B-AN-CP	20	25	0.09	7/5/11 9:45	7/5/11 10:45	1.5	reddish brown	25.3	8.44	13.38	4.94	NA	NA	NA

Table A.66. Datasheet for Column G4B Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				7/6/11 6:37										
G4B-EL-CP	60	25	0.08	7/6/11 6:37	7/6/11 16:37	1.2	brownish red	RT	14.92	58.08	43.16	8.46	17.42	8.96
G4B-EDI-CP	20	25	0.08	7/6/11 16:52	7/6/11 17:52	1.2	brownish red	RT	8.48	12.78	4.30	NA	NA	NA
G4B-RG-CP	20	25	0.09	7/6/11 18:03	7/6/11 20:03	1.6	brownish red	RT	8.48	20.98	12.50	NA	NA	NA

Table A.67. Datasheet for Column G5 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
G5-LD-0	20	60	NA	7/7/11 6:39	7/7/11 6:39	1. 5	brownish red	63.2	NA	NA	NA	8.44	11.85	3.41
Loading (LD) Phase Start Date/Time:				7/7/11 6:45										
G5-LD-006	20	60	10.62	7/7/11 6:51	7/7/11 6:51	NA	brownish red	57.2	NA	NA	NA	8.44	11.85	3.41
G5-LD-012	20	60	10.62	7/7/11 6:57	7/7/11 6:57	NA	brownish red	54.5	NA	NA	NA	8.54	11.88	3.34
G5-LD-018	20	60	10.62	7/7/11 7:03	7/7/11 7:03	NA	brownish red	53.2	NA	NA	NA	8.54	12.04	3.50
G5-LD-024	20	60	10.62	7/7/11 7:09	7/7/11 7:09	NA	brownish red	52.7	NA	NA	NA	8.49	11.82	3.33
G5-LD-036	20	60	10.62	7/7/11 7:21	7/7/11 7:21	NA	brownish red	53.5	NA	NA	NA	8.50	12.04	3.54
G5-LD-048	20	60	10.62	7/7/11 7:33	7/7/11 7:33	NA	brownish red	54.4	NA	NA	NA	8.51	11.80	3.29
G5-LD-060	20	60	10.62	7/7/11 7:45	7/7/11 7:45	NA	dark brown	55.0	NA	NA	NA	8.58	11.96	3.38

Table A.67. Datasheet for Column G5 Loading and Rinsing Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
G5-LD-080	20	60	10.62	7/7/11 8:05	7/7/11 8:05	NA	dark brown	55.2	NA	NA	NA	8.49	11.90	3.41
G5-LD-120	20	60	10.62	7/7/11 8:45	7/7/11 8:45	NA	dark brown	57.1	NA	NA	NA	8.52	12.01	3.49
G5-LD-180	20	60	10.62	7/7/11 9:45	7/7/11 9:45	NA	dark brown	57.8	NA	NA	NA	8.58	11.93	3.35
G5-LD-240	20	60	10.62	7/7/11 10:45	7/7/11 10:45	NA	dark brown	58.8	NA	NA	NA	8.48	11.94	3.46
G5-LD-600	20	60	10.62	7/7/11 16:45	7/7/11 16:45	NA	dark brown	60.4	NA	NA	NA	8.55	12.62	4.07
G5-FD-CP	20	60	0.09	7/7/11 17:10	7/7/11 19:40	1.5	dark brown	60.0	8.43	21.97	13.54	NA	NA	NA
G5-FDI-CP	20	25	0.09	7/7/11 19:58	7/7/11 22:28	1.5	dark brown	25.2	8.58	20.20	11.62	NA	NA	NA
G5-AN-CP	20	25	0.09	7/7/11 22:32	7/7/11 23:32	1.5	dark brown	25.2	8.39	13.01	4.62	NA	NA	NA

Table A.68. Datasheet for Column G5 Elution, Rinsing, and Regeneration Information

Sample ID No.	Bottle Size (mL)	Temp Set (°C)	Pump Setting (mL/min)	Sampling Start Time	Sampling Stop Time	Resin Height (cm)	Resin Color	Temp (°C)	Effluent Bottle Weight, g			Sample Vial Weight, g		
									Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				7/11/11 6:40										
G5-EL-CP	60	25	0.08	7/11/11 6:40	7/11/11 16:40	1.0	orange red	RT	14.93	57.74	42.81	8.52	19.26	10.74
G5-EDI-CP	20	25	0.08	7/11/11 16:48	7/11/11 17:48	1.2	orange red	RT	8.54	13.04	4.50	NA	NA	NA

Appendix B: Analytical Data

The corr. in the concentration columns is equal to the raw data multiplied by the dilution factor. This corrects the raw data based on the sample dilution.

Table B.1. Column A1 Test Analytical Data (T = 45°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
A1-LD-00	0	1	2.93	2450	94400	2.93	2450	94400	1.53	1.68	53600	20200	53600	20200
A1-LD-06	6	1	2.53	2370	90200	2.53	2370	90200	1.48	1.63	51400	19300	51400	19300
A1-LD-12	12	1	2.43	2390	91100	2.43	2390	91100	1.48	1.63	51200	19000	51200	19000
A1-LD-18	18	1	2.25	2370	89700	2.25	2370	89700	1.48	1.63	51400	19200	51400	19200
A1-LD-24	24	1	2.24	2390	91900	2.24	2390	91900	1.48	1.63	51600	19300	51600	19300
A1-LD-36	36	1	2.28	2390	91800	2.28	2390	91800	1.49	1.64	50900	19000	50900	19000
A1-LD-48	48	1	2.12	2410	91400	2.12	2410	91400	1.49	1.64	50400	18900	50400	18900
A1-LD-60	60	1	1.94	2370	91900	1.94	2370	91900	1.48	1.63	50500	19000	50500	19000
A1-LD-80	80	1	1.73	2380	90900	1.73	2380	90900	1.48	1.63	50400	19000	50400	19000
A1-LD-120	120	1	1.23	2400	90700	1.23	2400	90700	1.48	1.62	51300	19000	51300	19000
A1-LD-180	180	1	1.02	2340	87400	1.02	2340	87400	1.48	1.63	51000	19000	51000	19000
A1-LD-240	240	1	0.848	2370	88700	0.848	2370	88700	1.48	1.63	51800	19400	51800	19400
A1-LD-600	600	1	0.479	2360	90300	0.479	2360	90300	1.48	1.63	50600	19000	50600	19000
A1-FD-CP	Feed Displacement	1	0.278	1400	52700	0.278	1400	52700	0.886	0.963	29400	10900	29400	10900
A1-EL-CP	Elution	1	10.6	4.47	1150	10.6	4.47	1150	<0.05	<0.05	58.1	2780	58.1	2780
Target	--	--	--	--	--	2.62	2570	95000	1.55	2.01	--	--	48900	19300

Table B.2. Column A2 Test Analytical Data (T = 45°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
A2-LD-00	0	1.67	1.69	1600	74200	2.82	2670	124000	1.64	1.80	<34.0	40700	<56.7	67900
A2-LD-06	6	1.70	1.54	1540	70900	2.62	2620	121000	1.59	1.75	<34.4	38800	<58.5	66000
A2-LD-12	12	1.66	1.49	1570	72100	2.47	2610	120000	1.61	1.76	<33.7	39100	<56.0	64900
A2-LD-18	18	1.69	1.39	1500	69300	2.35	2530	117000	1.60	1.76	<33.9	38900	<57.2	65700
A2-LD-24	24	1.91	1.23	1370	62100	2.35	2620	119000	1.55	1.71	<34.4	33900	<65.7	64700
A2-LD-36	36	1.66	1.29	1530	69100	2.14	2540	115000	1.59	1.76	<33.8	39400	<56.1	65400
A2-LD-48	48	1.65	1.27	1580	70700	2.10	2610	117000	1.61	1.77	<34.1	40300	<56.4	66700
A2-LD-60	60	1.67	1.21	1590	73400	2.02	2650	122000	1.60	1.77	<33.6	39300	<56.0	65500
A2-LD-80	80	1.73	1.07	1510	69400	1.85	2610	120000	1.58	1.73	<33.9	37900	<58.7	65600
A2-LD-120	120	1.64	0.998	1570	72900	1.63	2570	119000	1.61	1.77	<33.5	39500	<54.8	64600
A2-LD-180	180	1.64	0.860	1560	71900	1.41	2560	118000	1.60	1.77	<33.5	39200	<54.9	64300
A2-LD-240	240	1.60	0.801	1630	73900	1.28	2620	119000	1.60	1.76	<33.5	40900	<53.7	65600
A2-LD-600	600	1.75	0.558	1530	70200	0.974	2670	123000	1.59	1.75	<33.7	37200	<58.8	64900
A2-FD-CP	Feed Displacement	1	0.637	1630	78500	0.637	1630	78500	1.11	1.21	125	40800	125	40800
A2-EL-CP	Elution	1	8.79	8.40	1420	8.79	8.40	1420	<0.05	<0.05	<40.2	2590	<40.2	2590
Target	--	--	--	--	--	2.79	2720	134000	1.86	2.41	--	--	0	61200

Table B.3. Column A3 Test Analytical Data (T = 45°C, Flow rate = 7.08 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
A3-LD-00	0	1.58	1.82	1660	76700	2.88	2630	121000	1.65	1.80	<33.1	41800	<52.4	66200
A3-LD-06	6	1.64	1.58	1540	70900	2.58	2520	116000	1.59	1.75	<33.8	40000	<55.3	65400
A3-LD-12	12	1.66	1.50	1550	71400	2.50	2580	119000	1.59	1.75	<33.7	38900	<56.1	64700
A3-LD-18	18	1.79	1.30	1420	65100	2.32	2540	116000	1.57	1.71	<34.2	36500	<61.1	65200
A3-LD-24	24	1.80	1.23	1400	63600	2.22	2520	115000	1.57	1.72	<34.2	35900	<61.6	64700
A3-LD-36	36	1.56	1.36	1640	74400	2.12	2560	116000	1.59	1.75	<33.0	40500	<51.5	63200
A3-LD-48	48	1.71	1.14	1500	68300	1.95	2570	117000	1.59	1.76	<33.8	37900	<57.8	64800
A3-LD-60	60	1.57	1.16	1610	73400	1.83	2540	116000	1.61	1.76	<33.2	41500	<52.3	65300
A3-LD-80	80	1.62	1.04	1570	71600	1.68	2540	116000	1.60	1.75	<33.6	40100	<54.3	64800
A3-LD-120	120	1.54	0.940	1660	75800	1.45	2560	117000	1.60	1.76	<33.2	41800	<51.2	64500
A3-LD-180	180	1.61	0.774	1590	73200	1.24	2560	118000	1.59	1.74	<33.4	40000	<53.7	64300
A3-LD-240	240	1.61	0.684	1590	72600	1.10	2560	117000	1.61	1.77	<33.6	40800	<54.0	65600
A3-LD-600	600	1.63	0.510	1580	71800	0.830	2570	117000	1.59	1.74	<33.4	39400	<54.4	64100
A3-FD-CP	Feed Displacement	1	0.585	1680	77700	0.585	1680	77700	1.16	1.26	110	42200	110	42200
A3-EL-CP	Elution	1	10.50	4.92	1160	10.5	4.92	1160	<0.05	<0.05	<40.3	2750	<40.3	2750
Target	--	--	--	--	--	2.79	2720	134000	1.86	2.41	--	--	0	61200

Table B.4. Column A4 Test Analytical Data (T = 45°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
A4-LD-00	0	1.65	3.71	3910	78700	6.11	6440	130000	3.23	3.61	<33.8	27100	<55.7	44700
A4-LD-06	6	1.76	3.18	3600	71700	5.59	6330	126000	3.11	3.46	<34.2	24400	<60.1	42900
A4-LD-12	12	1.61	3.38	4000	80200	5.44	6440	129000	3.17	3.54	<33.8	27000	<54.4	43500
A4-LD-18	18	1.67	3.00	3760	75400	5.02	6290	126000	3.16	3.53	<33.8	26000	<56.5	43500
A4-LD-24	24	1.66	2.92	3860	77100	4.84	6400	128000	3.15	3.53	<33.8	26100	<56.0	43300
A4-LD-36	36	1.63	2.74	3920	78400	4.48	6400	128000	3.17	3.51	<33.8	26300	<55.2	43000
A4-LD-48	48	1.68	2.46	3750	74400	4.12	6290	125000	3.12	3.50	<33.7	25600	<56.5	42900
A4-LD-60	60	1.66	2.46	3780	75900	4.08	6270	126000	3.14	3.52	<33.7	26100	<55.9	43300
A4-LD-80	80	1.60	2.52	4050	81200	4.04	6490	130000	3.16	3.54	<33.8	27200	<54.2	43600
A4-LD-120	120	1.64	2.27	3870	76700	3.73	6360	126000	3.15	3.52	<33.8	26600	<55.5	43700
A4-LD-180	180	1.72	2.03	3680	72900	3.50	6340	126000	3.12	3.48	<33.8	24900	<58.2	42900
A4-LD-240	240	1.64	2.01	3850	76600	3.29	6300	125000	3.17	3.52	<33.8	26200	<55.3	42800
A4-LD-600	600	1.65	1.58	3840	77300	2.60	6320	127000	3.16	3.52	<34.5	27100	<56.8	44600
A4-FD-CP	Feed Displacement	1	1.73	5480	114000	1.73	5480	114000	3.13	3.50	<31.3	38500	<31.3	38500
Target	--	--	--	--	--	5.68	6690	137000	3.67	5.00	--	--	0	40800

Table B.5. Column A4B Test Analytical Data (T = 45°C, Flow rate = 0.08 mL/min)

Sample ID	Loading Time (hrs)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
A4B-LD-00	0	1.61	3.84	4030	81300	6.20	6500	131000	3.31	3.66	<33.4	27400	<53.9	44200
A4B-LD-04	4	1.61	3.74	4020	78600	6.03	6480	127000	3.22	3.61	<33.5	27200	<54.0	43800
A4B-LD-08	8	1.63	3.57	4020	76300	5.83	6560	125000	3.22	3.59	<33.7	26500	<55.0	43300
A4B-LD-12	12	1.69	5.50	6190	119000	9.31	10500	201000	5.62	6.28	<31.5	41600	<53.3	70400
A4B-LD-24	24	1.56	4.95	5990	111000	7.71	9330	173000	4.67	5.23	<31.7	38600	<49.4	60100
A4B-LD-72	72	1.61	3.12	3980	80300	5.04	6430	130000	10.13	10.55	<33.4	27100	<53.9	43800
A4B-LD-120	120	1.62	2.77	3950	78100	4.50	6420	127000	3.25	3.64	<33.7	27100	<54.7	44000
A4B-LD-168	168	1.64	2.51	4020	80800	4.11	6590	132000	3.24	3.64	<33.7	27300	<55.2	44700
A4B-LD-336	336	1.67	1.99	4080	79800	3.32	6810	133000	3.24	3.66	<33.3	24700	<55.6	41200
A4B-LD-504	504	1.65	1.98	4010	82200	3.27	6630	136000	3.34	3.72	<33.6	25400	<55.5	42000
A4B-LD-672	672	1.63	2.03	4240	84800	3.32	6920	138000	3.38	3.80	<34.1	27200	<55.7	44400
A4B-LD-720	720	1.65	2.01	4060	82900	3.32	6700	137000	3.37	3.81	<34.2	26700	<56.4	44000
A4B-FD-CP	Feed Displacement	1	1.93	3560	75600	1.93	3560	75600	1.78	2.00	<37.7	21700	<37.7	21700
A4B-EL-CP	Elution	1	31.0	46.5	1610	31.0	46.5	1610	<0.05	<0.05	<40.6	2490	<40.6	2490
Target	--	--	--	--	--	5.68	6690	137000	3.67	5.00	--	--	0	40800

Table B.6. Column A5 Test Analytical Data (T = 45°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
A5-LD-00	0	1	2.98	2560	88200	2.98	2560	88200	1.55	1.70	51700	18500	51700	18500
A5-LD-06	6	1	2.49	2530	85600	2.49	2530	85600	1.50	1.66	50200	18200	50200	18200
A5-LD-12	12	1	2.15	2570	84900	2.15	2570	84900	1.50	1.67	49600	17800	49600	17800
A5-LD-18	18	1	1.91	2570	85500	1.91	2570	85500	1.51	1.66	50300	18100	50300	18100
A5-LD-24	24	1	1.73	2550	85500	1.73	2550	85500	1.50	1.65	50000	17900	50000	17900
A5-LD-36	36	1	1.45	2580	85000	1.45	2580	85000	1.50	1.65	49800	17700	49800	17700
A5-LD-48	48	1	1.29	2500	86500	1.29	2500	86500	1.49	1.65	49600	17900	49600	17900
A5-LD-60	60	1	1.18	2580	89300	1.18	2580	89300	1.51	1.66	50300	18000	50300	18000
A5-LD-80	80	1	1.01	2510	83600	1.01	2510	83600	1.50	1.65	51100	18400	51100	18400
A5-LD-120	120	1	0.828	2570	85000	0.828	2570	85000	1.50	1.65	49700	17900	49700	17900
A5-LD-180	180	1	0.702	2570	86700	0.702	2570	86700	1.50	1.65	50100	18000	50100	18000
A5-LD-240	240	1	0.644	2480	85000	0.644	2480	85000	1.50	1.65	49700	17900	49700	17900
A5-LD-600	600	1	0.620	2580	85100	0.620	2580	85100	1.50	1.65	50000	17800	50000	17800
A5-LD-900	900	1	0.649	2560	85200	0.649	2560	85200	1.51	1.66	51000	18300	51000	18300
A5-LD-1200	1200	1	0.646	2530	85600	0.646	2530	85600	1.51	1.66	49400	17800	49400	17800
A5-FD-CP	Feed Displacement	1	0.445	1500	51700	0.445	1500	51700	0.927	1.01	29700	10800	29700	10800
A5-EL-CP	Elution	1	11.2	7.16	950	11.2	7.16	950	<0.05	<0.05	<40.8	2490	<40.8	2490
Target	--	--	--	--	--	2.62	2570	95000	1.55	2.01	--	--	48900	19300

Table B.7. Column B1 Test Analytical Data (T = 50°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
B1-LD-00	0	1	3.18	2690	92900	3.18	2690	92900	1.56	1.71	50500	18200	50500	18200
B1-LD-06	6	1	2.60	2540	87900	2.60	2540	87900	1.50	1.65	48500	17500	48500	17500
B1-LD-12	12	1	2.32	2530	87800	2.32	2530	87800	1.50	1.66	49300	17700	49300	17700
B1-LD-18	18	1	2.04	2420	87300	2.04	2420	87300	1.49	1.64	50400	18200	50400	18200
B1-LD-24	24	1	1.87	2520	90500	1.87	2520	90500	1.49	1.65	48800	17400	48800	17400
B1-LD-36	36	1	1.55	2630	90300	1.55	2630	90300	1.49	1.65	49100	17600	49100	17600
B1-LD-48	48	1	1.22	2460	86000	1.22	2460	86000	1.50	1.64	49900	18000	49900	18000
B1-LD-60	60	1	1.09	2590	88200	1.09	2590	88200	1.50	1.65	48800	17700	48800	17700
B1-LD-80	80	1	0.930	2520	88600	0.930	2520	88600	1.49	1.64	48400	17400	48400	17400
B1-LD-120	120	1	0.699	2580	86900	0.699	2580	86900	1.50	1.65	49200	17600	49200	17600
B1-LD-180	180	1	0.562	2600	88800	0.562	2600	88800	1.50	1.64	49100	17700	49100	17700
B1-LD-240	240	1	0.500	2490	90000	0.500	2490	90000	1.49	1.64	49800	18000	49800	18000
B1-LD-600	600	1	0.382	2510	86900	0.382	2510	86900	1.50	1.65	49000	17600	49000	17600
B1-LD-900	900	1	0.383	2550	88700	0.383	2550	88700	1.49	1.64	48700	17700	48700	17700
B1-LD-1200	1200	1	0.402	2650	89500	0.402	2650	89500	1.51	1.66	49200	17700	49200	17700
B1-FD-CP	Feed Displacement	1	0.294	1590	55600	0.294	1590	55600	0.958	1.04	32100	11600	32100	11600
B1-EL-CP	Elution	1	11.5	4.17	1170	11.5	4.17	1170	<0.05	<0.05	<41.4	2500	<41.4	2500
Target	--	--	--	--	--	2.63	2570	95000	1.55	2.01	--	--	48900	19300

Table B.8. Column B2 Test Analytical Data (T = 50°C, Flow rate = 14.16 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
B2-LD-00	0	1	1.60	798	47900	1.60	798	47900	0.462	0.506	27000	8440	27000	8440
B2-LD-06	6	1	1.24	769	41500	1.24	769	41500	0.463	0.507	26000	8130	26000	8130
B2-LD-12	12	1	0.992	778	38300	0.992	778	38300	0.452	0.500	26100	8120	26100	8120
B2-LD-18	18	1	0.830	774	51200	0.830	774	51200	0.461	0.505	26000	8110	26000	8110
B2-LD-24	24	1	0.695	777	41300	0.695	777	41300	0.462	0.505	26200	8120	26200	8120
B2-LD-36	36	1	0.497	758	37000	0.497	758	37000	0.460	0.502	26000	8150	26000	8150
B2-LD-48	48	1	0.385	742	35600	0.385	742	35600	0.453	0.505	25900	8190	25900	8190
B2-LD-60	60	1	0.339	781	46500	0.339	781	46500	0.459	0.506	26000	8110	26000	8110
B2-LD-80	80	1	0.262	765	37400	0.262	765	37400	0.461	0.502	25700	8150	25700	8150
B2-LD-120	120	1	0.203	778	47700	0.203	778	47700	0.466	0.509	26100	8160	26100	8160
B2-LD-180	180	1	0.169	799	39800	0.169	799	39800	0.462	0.507	25700	8140	25700	8140
B2-LD-240	240	1	0.148	783	43200	0.148	783	43200	0.457	0.502	26300	8220	26300	8220
B2-LD-600	600	1	0.127	770	37100	0.127	770	37100	0.459	0.509	26600	8330	26600	8330
B2-LD-900	900	1	0.142	793	43400	0.142	793	43400	0.468	0.515	26500	8360	26500	8360
B2-LD-1200	1200	1	0.144	763	38300	0.144	763	38300	0.465	0.510	26300	8220	26300	8220
B2-FD-CP	Feed Displacement	1	0.104	477	26100	0.104	477	26100	0.334	0.362	15800	4720	15800	4720
B2-EL-CP	Elution	1	7.68	<2.00	1160	7.68	<2.00	1160	<0.05	<0.05	157	2310	157	2310
Target	--	--	--	--	--	1.71	808	42400	0.468	0.598	--	--	27200	8590

Table B.9. Column B3 Test Analytical Data (T = 50°C, Flow rate = 7.08 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
B3-LD-00	0	1	1.57	756	39300	1.57	756	39300	0.466	0.509	27300	8600	27300	8600
B3-LD-06	6	1	1.33	736	36600	1.33	736	36600	0.456	0.497	25700	7990	25700	7990
B3-LD-12	12	1	1.24	765	37500	1.24	765	37500	0.458	0.501	25700	8020	25700	8020
B3-LD-18	18	1	1.12	761	38200	1.12	761	38200	0.460	0.503	26400	8200	26400	8200
B3-LD-24	24	1	1.00	761	38400	1.00	761	38400	0.461	0.505	24900	7820	24900	7820
B3-LD-36	36	1	0.786	736	36800	0.786	736	36800	0.462	0.503	25500	7940	25500	7940
B3-LD-48	48	1	0.657	749	37800	0.657	749	37800	0.462	0.504	26000	8170	26000	8170
B3-LD-60	60	1	0.532	759	37200	0.532	759	37200	0.459	0.503	25600	8020	25600	8020
B3-LD-80	80	1	0.432	754	38100	0.432	754	38100	0.457	0.502	25600	8000	25600	8000
B3-LD-120	120	1	0.288	756	38600	0.288	756	38600	0.459	0.504	25700	8080	25700	8080
B3-LD-180	180	1	0.205	757	37700	0.205	757	37700	0.454	0.499	25600	8020	25600	8020
B3-LD-240	240	1	0.159	743	37800	0.159	743	37800	0.464	0.506	25900	8110	25900	8110
B3-LD-600	600	1	0.125	746	37200	0.125	746	37200	0.458	0.503	25800	8070	25800	8070
B3-LD-900	900	1	0.131	750	38100	0.131	750	38100	0.468	0.509	25800	8110	25800	8110
B3-LD-1200	1200	1	0.134	757	38500	0.134	757	38500	0.462	0.508	26300	8180	26300	8180
B3-FD-CP	Feed Displacement	1	0.104	442	23200	0.104	442	23200	0.333	0.363	15800	4650	15800	4650
B3-EL-CP	Elution	1	7.15	<2.00	1130	7.15	<2.00	1130	<0.05	<0.05	<101	2340	<101	2340
Target	--	--	--	--	--	1.71	808	42400	0.468	0.598	--	--	27200	8590

Table B.10. Column B4 Test Analytical Data (T = 50°C, Flow rate = 7.08 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
B4-LD-00	0	1.62	1.76	4240	78400	2.85	6870	127000	3.21	3.58	<86.1	24600	<140	39900
B4-LD-06	6	1.71	1.53	3720	71100	2.62	6370	122000	3.10	3.48	<85.9	22200	<147	38000
B4-LD-12	12	1.67	1.51	3990	74700	2.53	6680	125000	3.10	3.48	<84.7	22700	<142	38000
B4-LD-18	18	1.76	1.37	3860	70000	2.41	6780	123000	3.13	3.48	<85.3	21600	<150	37900
B4-LD-24	24	1.69	1.36	3990	72000	2.30	6750	122000	3.13	3.50	<86.1	22700	<146	38400
B4-LD-36	36	1.65	1.25	3910	72800	2.06	6460	120000	3.12	3.48	<84.7	23400	<140	38600
B4-LD-48	48	1.74	1.11	3530	69500	1.93	6150	121000	3.05	3.41	<85.9	21400	<150	37300
B4-LD-60	60	1.64	1.09	3660	72800	1.79	6000	119000	3.10	3.47	<84.7	23000	<139	37700
B4-LD-80	80	1.93	0.836	3190	61500	1.61	6150	119000	3.05	3.39	<87.0	19300	<168	37200
B4-LD-120	120	1.83	0.784	3550	68300	1.44	6510	125000	3.04	3.43	<86.2	20600	<158	37800
B4-LD-180	180	1.69	0.698	3840	71600	1.18	6500	121000	3.13	3.49	<85.5	22400	<145	37900
B4-LD-240	240	1.68	0.631	3910	73700	1.06	6570	124000	3.11	3.46	<88.2	23400	<148	39300
B4-LD-600	600	1.72	0.644	5050	98400	1.11	8700	170000	4.83	5.38	<80.0	32600	<138	56200
B4-FD-CP	Feed Displacement	1	0.630	4300	80400	0.630	4300	80400	2.14	2.38	<89.1	24600	<89.1	24600
Target	--	--	--	--	--	2.87	6710	137000	3.67	5.00	--	--	0	41700

Table B.11. Column B4B Test Analytical Data (T = 65°C, Flow rate = 0.08 mL/min)

Sample ID	Loading Time (hrs)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
B4B-LD-00	0	1.75	1.61	3520	70400	2.82	6160	123000	3.20	3.55	<86.5	22600	<151	39600
B4B-LD-04	4	1.72	1.58	3690	71300	2.72	6360	123000	3.12	3.48	<86.7	22200	<150	38300
B4B-LD-08	8	1.73	1.51	3440	69800	2.61	5940	120000	3.09	3.45	<85.3	22000	<147	38000
B4B-LD-12	12	1.68	1.55	4030	72400	2.61	6780	122000	3.11	3.50	<84.3	22600	<142	38000
B4B-LD-24	24	1.65	1.53	3860	76000	2.53	6380	126000	3.17	3.57	<84.9	23700	<140	39100
B4B-LD-72	72	1.63	1.49	4090	77200	2.43	6660	126000	3.24	3.63	<86.5	24200	<141	39400
B4B-LD-120	120	1.63	1.58	4220	79800	2.58	6890	130000	3.35	3.74	<83.5	24600	<136	40100
B4B-LD-168	168	1.66	1.59	4270	81100	2.65	7110	135000	3.38	3.78	<87.0	24300	<145	40500
B4B-LD-336	336	1.64	1.70	4470	86400	2.79	7320	142000	3.57	4.01	<82.5	26400	<135	43300
B4B-LD-504	504	1.65	1.90	4870	92400	3.13	8020	152000	3.84	4.32	<81.7	27500	<135	45300
B4B-FD-CP	Feed Displacement	1	0.198	106	5550	0.198	106	5550	0.18	0.19	313	805	313	805
B4B-EL-CP	Elution	1	9.18	255	1260	9.18	255	1260	<0.05	<0.05	<101	2400	<101	2400
Target	--	--	--	--	--	2.87	6710	137000	3.67	5.00	--	--	0	41700

Table B.12. Column B5 Test Analytical Data (T = 50°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
B5-LD-00	0	1	5.17	2670	94000	5.17	2670	94000	1.58	1.73	49900	18200	49900	18200
B5-LD-06	6	1	4.36	2520	89600	4.36	2520	89600	1.54	1.69	48900	17800	48900	17800
B5-LD-12	12	1	3.99	2510	89100	3.99	2510	89100	1.54	1.69	48700	17900	48700	17900
B5-LD-18	18	1	3.87	2600	93400	3.87	2600	93400	1.54	1.69	48800	17900	48800	17900
B5-LD-24	24	1	3.53	2550	90900	3.53	2550	90900	1.54	1.69	49000	17800	49000	17800
B5-LD-36	36	1	3.14	2560	89000	3.14	2560	89000	1.54	1.69	48900	17800	48900	17800
B5-LD-48	48	1	2.96	2610	92300	2.96	2610	92300	1.53	1.69	48600	17800	48600	17800
B5-LD-60	60	1	2.72	2540	90400	2.72	2540	90400	1.53	1.68	48600	17700	48600	17700
B5-LD-80	80	1	2.54	2600	90200	2.54	2600	90200	1.54	1.68	48500	17700	48500	17700
B5-LD-120	120	1	2.24	2510	88900	2.24	2510	88900	1.55	1.70	48900	17800	48900	17800
B5-LD-180	180	1	2.12	2520	88700	2.12	2520	88700	1.54	1.69	48700	17800	48700	17800
B5-LD-240	240	1	2.15	2720	92500	2.15	2720	92500	1.54	1.69	49300	18000	49300	18000
B5-LD-600	600	1	2.09	2550	89900	2.09	2550	89900	1.55	1.70	49000	18000	49000	18000
B5-FD-CP	Feed Displacement	1	1.59	1610	59400	1.59	1610	59400	1.03	1.12	30600	11400	30600	11400
B5-EL-CP	Elution	1	16.0	35.0	1220	16.0	35.0	1220	<0.05	<0.05	<100	2400	<100	2400
Target	--	--	--	--	--	2.62	2570	95000	1.55	2.01	--	--	48900	19300

Table B.13. Column C1 Test Analytical Data (T = 50°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
C1-LD-00	0	1	3.02	2600	92700	3.02	2600	92700	1.54	1.70	50800	18300	50800	18300
C1-LD-06	6	1	2.68	2570	91200	2.68	2570	91200	1.49	1.64	50000	17700	50000	17700
C1-LD-12	12	1	2.47	2570	88900	2.47	2570	88900	1.50	1.66	52700	18700	52700	18700
C1-LD-18	18	1	2.30	2600	89100	2.30	2600	89100	1.48	1.63	49700	17900	49700	17900
C1-LD-24	24	1	2.19	2540	88500	2.19	2540	88500	1.49	1.63	49400	17900	49400	17900
C1-LD-36	36	1	1.97	2500	88800	1.97	2500	88800	1.49	1.64	48700	17600	48700	17600
C1-LD-48	48	1	1.81	2710	89500	1.81	2710	89500	1.49	1.64	48900	17600	48900	17600
C1-LD-60	60	1	1.65	2590	89700	1.65	2590	89700	1.48	1.63	48900	17600	48900	17600
C1-LD-80	80	1	1.39	2490	87300	1.39	2490	87300	1.49	1.64	49800	17900	49800	17900
C1-LD-120	120	1	1.12	2570	88800	1.12	2570	88800	1.48	1.63	50000	17900	50000	17900
C1-LD-180	180	1	0.845	2550	88200	0.845	2550	88200	1.49	1.63	49200	17700	49200	17700
C1-LD-240	240	1	0.691	2630	89800	0.691	2630	89800	1.49	1.64	51400	18700	51400	18700
C1-LD-600	600	1	0.464	2580	88600	0.464	2580	88600	1.49	1.64	49900	18000	49900	18000
C1-LD-900	900	1	0.452	2520	87500	0.452	2520	87500	1.50	1.65	50100	18000	50100	18000
C1-LD-1200	1200	1	0.434	2660	88700	0.434	2660	88700	1.49	1.65	50800	18400	50800	18400
C1-FD-CP	Feed Displacement	1	0.420	2060	72900	0.420	2060	72900	1.21	1.33	39900	14400	39900	14400
C1-EL-CP	Elution	1	7.96	5.68	981	7.96	5.68	981	<0.05	<0.05	58.8	2250	58.8	2250
Target	--	--	--	--	--	2.62	2570	95000	1.55	2.01	--	--	48900	19300

Table B.14. Column C2 Test Analytical Data (T = 50°C, Flow rate = 14.16 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
C2-LD-00	0	1	1.63	1760	41100	1.63	1760	41100	0.938	1.03	11200	8590	11200	8590
C2-LD-06	6	1	1.36	1670	39500	1.36	1670	39500	0.912	1.01	11000	8340	11000	8340
C2-LD-12	12	1	1.19	1680	39000	1.19	1680	39000	0.912	1.00	11000	8310	11000	8310
C2-LD-18	18	1	1.10	1670	39800	1.10	1670	39800	0.901	1.00	10900	8320	10900	8320
C2-LD-24	24	1	0.980	1650	39000	0.980	1650	39000	0.917	1.02	10900	8330	10900	8330
C2-LD-36	36	1	0.813	1680	40200	0.813	1680	40200	0.901	1.00	11000	8320	11000	8320
C2-LD-48	48	1	0.636	1670	39500	0.636	1670	39500	0.901	0.995	11000	8450	11000	8450
C2-LD-60	60	1	0.525	1650	38700	0.525	1650	38700	0.907	1.00	11100	8460	11100	8460
C2-LD-80	80	1	0.402	1650	40100	0.402	1650	40100	0.912	1.01	11000	8420	11000	8420
C2-LD-120	120	1	0.274	1630	39800	0.274	1630	39800	0.912	1.01	10900	8420	10900	8420
C2-LD-180	180	1	0.201	1690	39300	0.201	1690	39300	0.907	1.00	11200	8580	11200	8580
C2-LD-240	240	1	0.152	787	38800	0.152	787	38800	0.455	0.499	25700	8040	25700	8040
C2-LD-600	600	1	0.130	1660	39700	0.130	1660	39700	0.922	1.02	11200	8420	11200	8420
C2-LD-900	900	1	0.132	1690	38500	0.132	1690	38500	0.917	1.02	11200	8540	11200	8540
C2-LD-1200	1200	1	0.137	1710	40300	0.137	1710	40300	0.917	1.03	11400	8720	11400	8720
C2-FD-CP	Feed Displacement	1	0.112	1090	28300	0.112	1090	28300	0.653	0.715	7170	5480	7170	5480
C2-EL-CP	Elution	1	7.94	<2.00	1030	7.94	<2.00	1030	<0.05	<0.05	<99.8	2240	<99.8	2240
Target	--	--	--	--	--	1.70	1670	42300	0.933	1.20	--	--	10900	8580

Table B.15. Column C3 Test Analytical Data (T = 50°C, Flow rate = 7.08 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
C3-LD-00	0	1	1.53	1570	38000	1.53	1570	38000	0.901	0.984	10800	8180	10800	8180
C3-LD-06	6	1	1.40	1530	37000	1.40	1530	37000	0.870	0.958	10500	7950	10500	7950
C3-LD-12	12	1	1.30	1510	36400	1.30	1510	36400	0.881	0.963	10400	7900	10400	7900
C3-LD-18	18	1	1.24	1560	36400	1.24	1560	36400	0.875	0.963	10500	8010	10500	8010
C3-LD-24	24	1	1.16	1510	35500	1.16	1510	35500	0.875	0.963	10400	7950	10400	7950
C3-LD-36	36	1	1.06	1570	37500	1.06	1570	37500	0.881	0.969	10400	8000	10400	8000
C3-LD-48	48	1	0.943	1550	36500	0.943	1550	36500	0.875	0.963	10500	8010	10500	8010
C3-LD-60	60	1	0.863	1560	37300	0.863	1560	37300	0.881	0.969	10400	7960	10400	7960
C3-LD-80	80	1	0.802	1580	38100	0.802	1580	38100	0.881	0.969	10500	8040	10500	8040
C3-LD-120	120	1	0.594	1560	36400	0.594	1560	36400	0.875	0.958	10500	8010	10500	8010
C3-LD-180	180	1	0.407	1540	36100	0.407	1540	36100	0.881	0.969	10600	8060	10600	8060
C3-LD-240	240	1	0.317	1540	36500	0.317	1540	36500	0.881	0.963	10400	7950	10400	7950
C3-LD-600	600	1	0.153	1550	36300	0.153	1550	36300	0.881	0.969	10600	8000	10600	8000
C3-LD-900	900	1	0.126	1540	37000	0.126	1540	37000	0.875	0.969	10700	8090	10700	8090
C3-LD-1200	1200	1	0.114	1470	36700	0.114	1470	36700	0.886	0.969	10500	8020	10500	8020
C3-FD-CP	Feed Displacement	1	0.103	938	24200	0.103	938	24200	0.591	0.648	6310	4810	6310	4810
C3-EL-CP	Elution	1	6.78	<2.01	1070	6.78	<2.01	1070	<0.05	<0.05	<100	2300	<100	2300
Target	--	--	--	--	--	1.70	1670	42300	0.933	1.20	--	--	10900	8580

Table B.16. Column C4 Test Analytical Data (T = 50°C, Flow rate = 14.16 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
C4-LD-00	0	1.53	2.42	4570	84500	3.71	7000	130000	3.30	3.68	<82.6	26000	<127	39900
C4-LD-06	6	1.62	2.04	3920	75600	3.31	6350	123000	3.19	3.55	<83.8	23900	<136	38700
C4-LD-12	12	1.66	1.89	3900	75200	3.13	6460	125000	3.15	3.51	<83.8	23000	<139	38100
C4-LD-18	18	1.66	1.80	3890	75600	2.99	6450	125000	3.15	3.53	<84.2	23400	<140	38800
C4-LD-24	24	1.65	1.72	3950	75000	2.83	6500	123000	3.16	3.52	<85.9	23200	<141	38200
C4-LD-36	36	1.68	1.54	3790	73500	2.59	6380	124000	3.13	3.50	<84.6	23000	<142	38700
C4-LD-48	48	1.71	1.47	3800	73800	2.52	6520	127000	3.12	3.50	<84.0	22300	<144	38200
C4-LD-60	60	1.73	1.33	3740	72200	2.30	6460	125000	3.07	3.44	<84.6	21900	<146	37800
C4-LD-80	80	1.66	1.27	3880	75900	2.10	6430	126000	3.13	3.50	<84.5	23100	<140	38300
C4-LD-120	120	1.70	1.08	3770	73400	1.84	6420	125000	3.10	3.49	<84.5	22500	<144	38300
C4-LD-180	180	1.67	0.929	3850	73800	1.56	6450	124000	3.15	3.52	<84.7	23000	<142	38500
C4-LD-240	240	1.71	0.836	3800	73100	1.43	6490	125000	3.13	3.49	<84.3	22300	<144	38100
C4-LD-600	600	1.70	0.653	3730	72500	1.11	6340	123000	3.10	3.49	<84.5	22600	<144	38400
C4-FD-CP	Feed Displacement	1	0.932	4540	86600	0.932	4540	86600	2.33	2.62	84.6	26800	84.6	26800
Target	--	--	--	--	--	2.86	6750	138000	3.67	5.00	--	--	0	41900

Table B.17. Column C4B Test Analytical Data (T = 75°C, Flow rate = 0.08 mL/min)

Sample ID	Loading Time (hrs)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
C4B-LD-00	0	1.82	1.94	3550	68500	3.52	6440	124000	3.21	3.58	<84.7	21600	<153.7	39200
C4B-LD-04	4	1.73	2.15	4000	76800	3.71	6900	133000	3.47	3.87	<82.9	24100	<143.1	41600
C4B-LD-08	8	1.66	2.09	3890	74900	3.46	6450	124000	3.18	3.55	<84.5	23400	<140.0	38800
C4B-LD-12	12	1.64	2.13	3990	77400	3.50	6550	127000	3.17	3.53	<83.9	23700	<137.8	38900
C4B-LD-24	24	1.70	2.07	3900	76200	3.51	6610	129000	3.19	3.56	<85.6	23200	<145.1	39300
C4B-EL-NEW	New Feed	1.73	2.04	3990	73500	3.53	6900	127000	3.13	3.53	<84.9	22400	<146.8	38700
C4B-LD-72	72	1.67	2.23	4340	81500	3.72	7240	136000	3.37	3.79	<85.0	24600	<141.8	41000
C4B-LD-120	120	1.75	2.16	3980	75600	3.79	6980	133000	3.24	3.65	<84.6	22700	<148.3	39800
C4B-LD-168	168	1.67	2.35	4200	80100	3.93	7030	134000	3.35	3.75	<87.1	24600	<145.7	41100
C4B-LD-336	336	1.72	2.76	4900	92000	4.76	8450	159000	4.09	4.57	<82.1	28400	<141.5	49000
C4B-FD-CP	Feed Displacement	1	0.187	133	4220	0.187	133	4220	0.136	0.147	163	630	163	630
C4B-EL-CP	Elution	1	6.00	650	1650	6.00	650	1650	<0.05	<0.05	<99.2	2650	<99.2	2650
Target	--	--	--	--	--	3.73	6710	137000	3.67	5.00	--	--	0	41700

Table B.18. Column C5 Test Analytical Data (T = 50°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
C5-LD-00	0	1	5.05	2700	90500	5.05	2700	90500	1.57	1.72	49200	18100	49200	18100
C5-LD-06	6	1	4.45	2610	89600	4.45	2610	89600	1.54	1.69	48400	17700	48400	17700
C5-LD-12	12	1	4.10	2600	88700	4.10	2600	88700	1.53	1.68	47900	17600	47900	17600
C5-LD-18	18	1	3.74	2610	89400	3.74	2610	89400	1.52	1.67	47900	17600	47900	17600
C5-LD-24	24	1	3.38	2520	84900	3.38	2520	84900	1.51	1.66	47800	17500	47800	17500
C5-LD-36	36	1	3.16	2620	88300	3.16	2620	88300	1.51	1.66	47600	17400	47600	17400
C5-LD-48	48	1	2.98	2670	90800	2.98	2670	90800	1.52	1.66	48100	17500	48100	17500
C5-LD-60	60	1	2.80	2600	87500	2.80	2600	87500	1.53	1.67	48000	17600	48000	17600
C5-LD-80	80	1	2.68	2650	88200	2.68	2650	88200	1.52	1.66	47700	17500	47700	17500
C5-LD-120	120	1	2.58	2590	87400	2.58	2590	87400	1.52	1.66	48000	17500	48000	17500
C5-LD-180	180	1	2.40	2640	87700	2.40	2640	87700	1.52	1.67	47700	17500	47700	17500
C5-LD-240	240	1	2.38	2620	86200	2.38	2620	86200	1.52	1.67	47900	17500	47900	17500
C5-LD-600	600	1	2.43	2620	87800	2.43	2620	87800	1.52	1.67	48200	17600	48200	17600
C5-FD-CP	Feed Displacement	1	0.559	458	17800	0.559	458	17800	0.327	0.358	8390	3260	8390	3260
C5-EL-CP	Elution	1	11.2	158	1050	11.2	158	1050	<0.05	<0.05	<102	2280	<102	2280
Target	--	--	--	--	--	2.62	2570	95000	1.55	2.01	--	--	48900	19300

Table B.19. Column D1 Test Analytical Data (T = 25°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
D1-LD-00	0	1	2.96	2610	89400	2.96	2610	89400	1.52	1.68	50500	18600	50500	18600
D1-LD-06	6	1	2.56	2620	85200	2.56	2620	85200	1.48	1.63	48500	17800	48500	17800
D1-LD-12	12	1	2.32	2490	85300	2.32	2490	85300	1.48	1.63	49500	18200	49500	18200
D1-LD-18	18	1	2.11	2430	82900	2.11	2430	82900	1.48	1.63	49700	18300	49700	18300
D1-LD-24	24	1	1.98	2440	84100	1.98	2440	84100	1.48	1.63	46500	17000	46500	17000
D1-LD-36	36	1	1.69	2510	84000	1.69	2510	84000	1.48	1.64	49000	18100	49000	18100
D1-LD-48	48	1	1.56	2540	85100	1.56	2540	85100	1.48	1.63	48900	18000	48900	18000
D1-LD-60	60	1	1.42	2570	84700	1.42	2570	84700	1.48	1.63	48700	17900	48700	17900
D1-LD-80	80	1	1.25	2510	83900	1.25	2510	83900	1.47	1.63	48600	17900	48600	17900
D1-LD-120	120	1	0.946	2470	82600	0.946	2470	82600	1.48	1.63	48600	18000	48600	18000
D1-LD-180	180	1	0.673	2520	84900	0.673	2520	84900	1.49	1.64	49200	18100	49200	18100
D1-LD-240	240	1	0.531	2580	84400	0.531	2580	84400	1.48	1.63	49800	18300	49800	18300
D1-LD-600	600	1	0.260	2540	84600	0.260	2540	84600	1.47	1.63	48100	17600	48100	17600
D1-FD-CP	Feed Displacement	1	0.189	1760	61300	0.189	1760	61300	1.09	1.19	33700	12200	33700	12200
D1-EL-CP	Elution	1	<0.00016	<2.0	<10.0	<0.00016	<2.0	<10.0	<0.05	<0.05	<39.6	2450	<39.6	2450
Target	--	--	--	--	--	2.62	2570	95000	1.55	2.01	--	--	48900	19300

Table B.20. Column E1 Test Analytical Data (T = 50°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
E1-LD-00	0	1	3.59	2930	113000	3.59	2930	113000	1.97	2.16	66700	25300	66700	25300
E1-LD-06	6	1	3.00	2890	112000	3.00	2890	112000	1.86	2.05	62700	23600	62700	23600
E1-LD-12	12	1	2.82	2870	110000	2.82	2870	110000	1.88	2.06	60800	23000	60800	23000
E1-LD-18	18	1	2.53	2830	108000	2.53	2830	108000	1.88	2.06	62900	23700	62900	23700
E1-LD-24	24	1	2.35	2820	108000	2.35	2820	108000	1.89	2.07	62100	23600	62100	23600
E1-LD-36	36	1	2.00	2850	109000	2.00	2850	109000	1.89	2.07	62800	23500	62800	23500
E1-LD-48	48	1	1.74	2780	107000	1.74	2780	107000	1.89	2.07	60500	23000	60500	23000
E1-LD-60	60	1	1.57	2750	106000	1.57	2750	106000	1.88	2.07	60500	22900	60500	22900
E1-LD-80	80	1	1.35	2780	106000	1.35	2780	106000	1.90	2.08	61900	23500	61900	23500
E1-LD-120	120	1	1.01	2850	110000	1.01	2850	110000	1.88	2.07	61000	23300	61000	23300
E1-LD-180	180	1	0.856	2810	108000	0.856	2810	108000	1.89	2.07	62400	23500	62400	23500
E1-LD-240	240	1	0.663	2810	109000	0.663	2810	109000	1.88	2.07	61000	23800	61000	23800
E1-LD-600	600	1	0.532	2780	109000	0.532	2780	109000	1.89	2.08	61900	23200	61900	23200
E1-FD-CP	Feed Displacement	1	0.456	2070	80800	0.456	2070	80800	1.38	1.51	44300	16700	44300	16700
E1-EL-CP	Elution	1	10.4	5.65	1090	10.4	5.65	1090	<0.05	<0.05	81.1	2490	81.1	2490
Target	--	--	--	--	--	2.62	2570	95000	1.55	2.01	--	--	48900	19300

Table B.21. Column E2 Test Analytical Data (T = 50°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
E2-LD-00	0	1.60	1.99	1620	75600	3.19	2600	121000	1.65	1.79	<33.8	40600	<54.1	65000
E2-LD-06	6	1.67	1.68	1500	69900	2.81	2500	117000	1.59	1.74	<33.9	38200	<56.7	63871
E2-LD-12	12	1.62	1.65	1570	72700	2.68	2550	118000	1.60	1.75	<33.5	39000	<54.3	63272
E2-LD-18	18	1.59	1.54	1570	72800	2.45	2500	116000	1.59	1.75	<33.1	39800	<52.7	63334
E2-LD-24	24	1.63	1.44	1550	71900	2.35	2530	117000	1.59	1.75	<33.5	38700	<54.7	63194
E2-LD-36	36	1.60	1.32	1570	72600	2.11	2510	116000	1.60	1.74	<33.4	40400	<53.3	64450
E2-LD-48	48	1.64	1.18	1550	71800	1.93	2540	118000	1.59	1.73	<33.6	39300	<55.0	64320
E2-LD-60	60	1.66	1.08	1540	70800	1.79	2560	117000	1.58	1.74	<33.7	38500	<55.9	63875
E2-LD-80	80	1.62	0.983	1550	70900	1.60	2520	115000	1.59	1.74	<33.5	38900	<54.3	63110
E2-LD-120	120	1.65	0.820	1530	70900	1.35	2520	117000	1.59	1.73	<33.5	38300	<55.2	63082
E2-LD-180	180	1.66	0.683	1500	69200	1.13	2490	115000	1.58	1.74	<33.8	38300	<56.1	63597
E2-LD-240	240	1.64	0.616	1510	70100	1.01	2480	115000	1.58	1.74	<33.6	39000	<55.1	63984
E2-LD-600	600	1.63	0.498	1580	72900	0.809	2570	118000	1.59	1.74	<33.5	39300	<54.4	63863
E2-FD-CP	Feed Displacement	1	0.659	1890	94200	0.659	1890	94200	1.37	1.50	<32.5	48400	<32.5	48400
E2-EL-CP	Elution	1	13.3	5.44	1340	13.3	5.44	1340	<0.05	<0.05	<40.2	2660	<40.2	2660
Target	--	--	--	--	--	2.79	2720	134000	1.86	2.41	--	--	0	61248

Table B.22. Column E3 Test Analytical Data (T = 50°C, Flow rate = 7.08 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
E3-LD-00	0	1.64	1.78	1740	78900	2.91	2850	129000	1.67	1.83	<33.2	41200	<54.3	67400
E3-LD-06	6	1.64	1.66	1710	77600	2.72	2800	127000	1.62	1.78	<33.3	39800	<54.5	65200
E3-LD-12	12	1.67	1.59	1700	75200	2.66	2840	126000	1.62	1.77	<33.6	39400	<56.1	65800
E3-LD-18	18	1.66	1.56	1680	78200	2.58	2780	129000	1.63	1.79	<33.5	40600	<55.4	67200
E3-LD-24	24	1.63	1.54	1700	77700	2.52	2780	127000	1.63	1.80	<33.8	40100	<55.3	65500
E3-LD-36	36	1.65	1.45	1750	76900	2.39	2890	127000	1.62	1.78	<33.6	40300	<55.5	66600
E3-LD-48	48	1.68	1.35	1670	75600	2.27	2810	127000	1.61	1.78	<33.4	39300	<56.2	66200
E3-LD-60	60	1.65	1.35	1760	77400	2.23	2910	128000	1.62	1.78	<33.4	39800	<55.2	65800
E3-LD-80	80	1.64	1.23	1690	76500	2.02	2770	125000	1.63	1.79	<33.6	40700	<55.1	66700
E3-LD-120	120	1.68	0.983	1640	74500	1.65	2760	125000	1.62	1.78	<33.6	39700	<56.4	66700
E3-LD-180	180	1.68	0.841	1680	75900	1.41	2820	127000	1.62	1.78	<33.6	39400	<56.4	66100
E3-LD-240	240	1.63	0.741	1650	77800	1.21	2690	127000	1.62	1.80	<33.2	40200	<54.2	65600
E3-LD-600	600	1.64	0.544	1700	77500	0.890	2780	127000	1.64	1.80	<33.4	40500	<54.6	66300
E3-FD-CP	Feed Displacement	1	0.787	2110	97500	0.787	2110	97500	1.38	1.52	<32.9	51200	<32.9	51200
E3-EL-CP	Elution	1	12.6	3.71	25.4	12.6	3.71	25.4	<0.05	<0.05	<40.2	2700	<40.2	2700
Target	--	--	--	--	--	2.79	2720	134000	1.86	2.41	--	--	0	61200

Table B.23. Column E4 Test Analytical Data (T = 50°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
E4-LD-00	0	1.56	4.03	4460	85600	6.29	6960	134000	3.31	3.71	<33.3	28900	<52.0	45100
E4-LD-06	6	1.66	3.39	4090	78300	5.61	6773	130000	3.15	3.53	<33.9	26200	<56.1	43400
E4-LD-12	12	1.59	3.24	4130	80000	5.16	6581	127000	3.17	3.54	<33.9	27200	<54.0	43300
E4-LD-18	18	1.63	2.97	4170	78300	4.84	6799	128000	3.18	3.55	<34.4	27000	<56.1	44000
E4-LD-24	24	1.62	2.88	4360	80100	4.66	7054	130000	3.17	3.54	<33.7	26600	<54.5	43000
E4-LD-36	36	1.60	2.54	4090	78800	4.07	6562	126000	3.16	3.55	<33.7	26900	<54.1	43200
E4-LD-48	48	1.62	2.32	4200	78200	3.76	6810	127000	3.15	3.52	<33.8	26600	<54.8	43100
E4-LD-60	60	1.61	2.16	4250	78600	3.48	6844	127000	3.17	3.54	<33.8	26900	<54.4	43300
E4-LD-80	80	1.63	1.98	4330	78700	3.23	7062	128000	3.20	3.57	<32.7	26000	<53.3	42404
E4-LD-120	120	1.61	1.70	4220	79900	2.74	6795	129000	3.20	3.57	<33.7	27000	<54.3	43500
E4-LD-180	180	1.63	1.43	4200	79500	2.33	6845	130000	3.19	3.57	<33.8	26500	<55.1	43200
E4-LD-240	240	1.64	1.26	4120	78700	2.07	6761	129000	3.18	3.54	<33.7	26200	<55.3	43000
E4-LD-600	600	1.61	1.00	4250	79100	1.61	6856	128000	3.19	3.57	<33.8	27100	<54.5	43700
E4-FD-CP	Feed Displacement	1	1.46	5170	100000	1.46	5170	100000	2.65	2.94	<32.4	32000	<32.4	32000
Target	--	--	--	--	--	5.68	6690	136509	3.67	5.00	--	--	0	40800

Table B.24. Column E4B Test Analytical Data (T = 50°C, Flow rate = 0.08 mL/min)

Sample ID	Loading Time (hrs)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
E4B-LD-00	0	1.59	3.98	4190	82400	6.33	6660	131000	3.29	3.69	<33.2	28300	<52.8	45000
E4B-LD-04	4	1.60	3.76	3980	79700	6.02	6370	128000	3.19	3.55	<33.2	26800	<53.2	42900
E4B-LD-08	8	1.59	3.67	4080	80100	5.84	6500	128000	3.20	3.57	<34.4	27300	<54.8	43500
E4B-LD-12	12	1.68	3.30	3830	74700	5.56	6450	126000	3.17	3.54	<33.4	25400	<56.3	42800
E4B-LD-24	24	1.74	3.06	4200	78700	5.31	7290	137000	4.05	4.53	<33.6	31300	<58.3	54400
E4B-LD-72	72	1.62	2.36	3970	78800	3.82	6420	127000	3.22	3.59	<33.7	27100	<54.5	43800
E4B-LD-120	120	1.64	2.30	3990	78700	3.77	6540	129000	3.26	3.65	<33.4	26900	<54.7	44100
E4B-LD-168	168	1.70	2.29	3880	76700	3.89	6600	130000	3.25	3.64	<33.8	26900	<57.4	45700
E4B-LD-336	336	1.60	2.40	4260	86100	3.83	6810	138000	3.50	3.95	<32.8	27800	<52.4	44400
E4B-LD-504	504	1.56	2.47	4470	89600	3.92	7100	142000	3.57	4.05	<35.7	31100	<56.7	49400
E4B-LD-672	672	1.61	2.57	4600	92200	4.14	7410	148000	3.78	4.28	<32.8	29900	<52.8	48200
E4B-LD-720	720	1.59	2.60	4560	93700	4.14	7240	149000	3.78	4.29	<32.8	30800	<52.1	48900
E4B-FD-CP	Feed Displacement	1	1.87	3370	68100	1.87	3370	68100	1.76	1.98	132	21300	132	21300
E4B-EL-CP	Elution	1	35.7	79.2	1390	35.7	79.2	1390	<0.05	<0.05	<43.9	2760	<43.9	2760
Target	--	--	--	--	--	5.68	6690	137000	3.67	5.00	--	--	0	40800

Table B.25. Column E5 Test Analytical Data (T = 50°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
E5-LD-00	0	1	3.20	2760	91500	3.20	2760	91500	1.55	1.71	52200	18900	52200	18900
E5-LD-06	6	1	2.38	2440	85200	2.38	2440	85200	1.51	1.66	49500	17600	49500	17600
E5-LD-12	12	1	2.06	2480	86400	2.06	2480	86400	1.50	1.65	49200	17700	49200	17700
E5-LD-18	18	1	1.81	2550	85500	1.81	2550	85500	1.49	1.65	49400	17900	49400	17900
E5-LD-24	24	1	1.59	2500	84200	1.59	2500	84200	1.50	1.66	49000	17600	49000	17600
E5-LD-36	36	1	1.32	2470	84500	1.32	2470	84500	1.50	1.65	49700	17900	49700	17900
E5-LD-48	48	1	1.15	2500	84500	1.15	2500	84500	1.49	1.65	49400	17800	49400	17800
E5-LD-60	60	1	1.09	2500	84600	1.09	2500	84600	1.50	1.66	50000	17900	50000	17900
E5-LD-80	80	1	0.910	2500	84200	0.910	2500	84200	1.49	1.65	50800	18200	50800	18200
E5-LD-120	120	1	0.551	2570	86100	0.551	2570	86100	1.51	1.66	49500	17800	49500	17800
E5-LD-180	180	1	0.476	2500	84700	0.476	2500	84700	1.50	1.66	50500	18100	50500	18100
E5-LD-240	240	1	0.472	2430	84000	0.472	2430	84000	1.51	1.66	51100	18400	51100	18400
E5-LD-600	600	1	0.534	2530	84900	0.534	2530	84900	1.50	1.66	49700	17800	49700	17800
E5-LD-900	900	1	0.566	2530	84200	0.566	2530	84200	1.51	1.67	50000	18200	50000	18200
E5-LD-1200	1200	1	0.594	2530	87100	0.594	2530	87100	1.52	1.68	50300	18100	50300	18100
E5-FD-CP	Feed Displacement	1	0.515	1880	64400	0.515	1880	64400	1.12	1.23	36500	13000	36500	13000
E5-EL-CP	Elution	1	10.1	12.0	1260	10.1	12.0	1260	<0.05	<0.05	<40.0	2330	<40.0	2330
Target	--	--	--	--	--	2.62	2570	95000	1.55	2.01	--	--	48900	19300

Table B.26. Column F1 Test Analytical Data (T = 55°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
F1-LD-00	0	1	2.12	2550	92900	2.12	2550	92900	1.59	1.74	49500	18000	49500	18000
F1-LD-06	6	1	1.74	2380	88700	1.74	2380	88700	1.52	1.67	48000	17400	48000	17400
F1-LD-12	12	1	1.53	2440	90700	1.53	2440	90700	1.51	1.66	47800	17500	47800	17500
F1-LD-18	18	1	1.36	2440	90200	1.36	2440	90200	1.52	1.66	47700	17600	47700	17600
F1-LD-24	24	1	1.21	2470	89800	1.21	2470	89800	1.51	1.66	47500	17600	47500	17600
F1-LD-36	36	1	1.01	2460	90100	1.01	2460	90100	1.51	1.65	47800	17700	47800	17700
F1-LD-48	48	1	0.863	2390	90500	0.863	2390	90500	1.51	1.65	47400	17400	47400	17400
F1-LD-60	60	1	0.729	2480	89700	0.729	2480	89700	1.51	1.66	47900	17600	47900	17600
F1-LD-80	80	1	0.618	2430	90900	0.618	2430	90900	1.51	1.65	47600	17400	47600	17400
F1-LD-120	120	1	0.476	2450	88800	0.476	2450	88800	1.52	1.66	47600	17500	47600	17500
F1-LD-180	180	1	0.378	2440	91200	0.378	2440	91200	1.52	1.66	47800	17500	47800	17500
F1-LD-240	240	1	0.329	2430	90200	0.329	2430	90200	1.51	1.66	47100	17400	47100	17400
F1-LD-600	600	1	0.268	2440	92100	0.268	2440	92100	1.52	1.67	47500	17300	47500	17300
F1-FD-CP	Feed Displacement	1	0.190	1340	51900	0.190	1340	51900	0.880	0.960	25400	9390	25400	9390
F1-EL-CP	Elution	1	7.52	3.15	1110	7.52	3.15	1110	<0.05	<0.05	<98.2	2330	<98.2	2330
Target	--	--	--	--	--	2.63	2570	95000	1.55	2.01	--	--	48900	19300

Table B.27. Column F2 Test Analytical Data (T = 55°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
F2-LD-00	0	1.75	1.78	1550	76900	3.12	2710	135000	1.63	1.79	<83.1	33400	<145	58500
F2-LD-06	6	1.85	1.49	1460	70400	2.76	2710	130000	1.56	1.71	<86.2	30800	<160	57100
F2-LD-12	12	2.02	1.26	1290	64400	2.54	2600	130000	1.52	1.68	<85.6	28200	<173	56800
F2-LD-18	18	1.91	1.24	1420	68100	2.36	2710	130000	1.56	1.71	<84.7	29700	<162	56600
F2-LD-24	24	1.88	1.18	1390	69400	2.22	2610	130000	1.53	1.67	<84.5	30000	<159	56300
F2-LD-36	36	1.89	1.08	1420	69800	2.04	2680	132000	1.57	1.71	<84.0	30100	<159	56900
F2-LD-48	48	1.86	0.997	1400	70700	1.86	2610	132000	1.55	1.70	<84.3	30200	<157	56300
F2-LD-60	60	1.89	0.893	1390	68500	1.69	2630	130000	1.55	1.71	<84.7	30000	<160	56800
F2-LD-80	80	1.94	0.778	1380	67200	1.51	2670	130000	1.53	1.68	<84.6	28900	<164	55900
F2-LD-120	120	1.93	0.657	1370	66300	1.27	2650	128000	1.55	1.70	<84.9	29300	<164	56600
F2-LD-180	180	1.82	0.587	1480	71100	1.07	2700	130000	1.57	1.72	<86.1	30900	<157	56300
F2-LD-240	240	1.99	0.495	1340	65200	0.987	2670	130000	1.56	1.72	<84.7	28400	<169	56600
F2-LD-600	600	1.74	0.472	1500	75600	0.823	2620	132000	1.58	1.74	<82.4	33000	<144	57500
F2-FD-CP	Feed Displacement	1	0.603	1550	79900	0.603	1550	79900	0.880	1.14	145	34000	145	34000
F2-EL-CP	Elution	1	7.12	4.31	1210	7.12	4.31	1210	<0.05	<0.05	<99.0	2380	<99.0	2380
Target	--	--	--	--	--	2.81	2720	134000	1.86	2.41	--	--	0	61200

Table B.28. Column F3 Test Analytical Data (T = 55°C, Flow rate = 7.08 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
F3-LD-00	0	1.78	1.80	1510	74300	3.21	2690	132000	1.63	1.78	<83.8	33100	<149	59000
F3-LD-06	6	1.72	1.71	1560	75700	2.94	2690	130000	1.58	1.72	<83.6	33200	<144	57100
F3-LD-12	12	1.82	1.53	1490	73100	2.78	2710	133000	1.56	1.72	<84.5	31000	<154	56300
F3-LD-18	18	1.76	1.45	1550	73900	2.56	2740	130000	1.58	1.74	<85.2	32100	<150	56600
F3-LD-24	24	1.75	1.46	1510	76000	2.55	2640	133000	1.58	1.74	<85.8	32600	<150	56900
F3-LD-36	36	1.81	1.21	1420	70800	2.19	2570	128000	1.56	1.72	<85.5	31500	<155	56900
F3-LD-48	48	1.81	1.14	1510	73100	2.06	2740	132000	1.57	1.73	<85.5	31200	<155	56500
F3-LD-60	60	1.77	1.06	1470	73000	1.87	2600	129000	1.58	1.74	<84.9	32100	<150	56800
F3-LD-80	80	1.77	0.972	1470	73400	1.72	2610	130000	1.58	1.74	<84.2	31800	<149	56400
F3-LD-120	120	1.74	0.813	1490	74500	1.41	2590	130000	1.59	1.74	<84.0	32600	<146	56700
F3-LD-180	180	1.75	0.714	1560	74900	1.25	2730	131000	1.57	1.74	<83.8	32400	<146	56600
F3-LD-240	240	1.79	0.627	1480	72900	1.12	2650	130000	1.58	1.73	<84.3	31700	<151	56700
F3-LD-600	600	1.72	0.538	1550	75800	0.920	2660	130000	1.60	1.75	<85.5	33200	<147	57000
F3-FD-CP	Feed Displacement	1	0.773	1690	85300	0.773	1690	85300	1.12	1.22	109	36200	109	36200
F3-EL-CP	Elution	1	7.12	4.05	1210	7.12	4.05	1210	<0.05	<0.05	<100	2540	<100	2540
Target	--	--	--	--	--	2.81	2720	134000	1.86	2.41	--	--	0	61200

Table B.29. Column F4 Test Analytical Data (T = 55°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
F4-LD-00	0	1.87	3.46	3620	74300	6.48	6780	139000	3.24	3.62	<84.2	21100	<158	39500
F4-LD-06	6	1.93	2.86	3300	68100	5.51	6360	131000	3.10	3.45	<85.5	19300	<165	37200
F4-LD-12	12	1.81	2.82	3570	73000	5.12	6480	132000	3.14	3.50	<84.5	20800	<153	37700
F4-LD-18	18	1.81	2.61	3470	73500	4.73	6290	133000	3.16	3.50	<84.5	20600	<153	37400
F4-LD-24	24	1.88	2.35	3450	70800	4.41	6470	133000	3.15	3.49	<84.5	20100	<159	37700
F4-LD-36	36	1.91	2.07	3330	70100	3.95	6360	134000	3.09	3.46	<84.6	19400	<162	37100
F4-LD-48	48	1.81	1.97	3700	73800	3.57	6710	134000	3.12	3.50	<85.2	20700	<155	37500
F4-LD-60	60	1.82	1.80	3530	73200	3.28	6440	134000	3.14	3.50	<85.3	20600	<156	37600
F4-LD-80	80	1.85	1.54	3490	71300	2.85	6450	132000	3.12	3.49	<85.6	20300	<158	37500
F4-LD-120	120	1.85	1.31	3570	72800	2.43	6620	135000	3.11	3.48	<84.2	20400	<156	37800
F4-LD-180	180	1.83	1.11	3470	72300	2.03	6360	132000	3.13	3.48	<84.3	20200	<155	37000
F4-LD-240	240	1.82	0.995	3600	74200	1.81	6560	135000	3.12	3.48	<84.0	20600	<153	37600
F4-LD-600	600	1.79	0.832	3510	74000	1.49	6280	132000	3.18	3.52	<85.3	21100	<153	37700
F4-FD-CP	Feed Displacement	1	1.27	4100	87300	1.27	4100	87300	2.19	2.43	<94.0	24200	<94.0	24200
Target	--	--	--	--	--	5.72	6690	137000	3.67	5.00	--	--	0	40800

Table B.30. Column F4B Test Analytical Data (T = 55°C, Flow rate = 0.08 mL/min)

Sample ID	Loading Time (hrs)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
F4B-LD-00	0	1.98	3.37	3490	69900	6.68	6920	139000	3.27	3.65	<85.6	19700	<170	39100
F4B-LD-04	4	1.89	3.23	3490	71200	6.12	6610	135000	3.13	3.49	<85.9	19800	<163	37500
F4B-LD-08	8	1.74	3.43	3670	75900	5.98	6390	132000	3.15	3.50	<84.6	21500	<147	37500
F4B-LD-12	12	1.78	3.16	3580	75500	5.64	6390	135000	3.14	3.52	<85.0	21500	<152	38400
F4B-LD-24	24	1.78	2.99	3740	76300	5.32	6660	136000	3.22	3.56	<84.6	21300	<151	37930
F4B-LD-72	72	1.81	2.04	3680	74600	3.70	6680	135000	3.18	3.54	<84.0	21000	<152	38100
F4B-LD-120	120	1.77	1.22	3840	77300	2.16	6790	137000	3.25	3.64	<84.6	21800	<150	38600
F4B-LD-168	168	1.82	2.07	3630	76200	3.77	6610	139000	3.24	3.61	<84.3	21200	<154	38600
F4B-LD-336	336	2.04	2.16	3470	70900	4.40	7060	144000	3.34	3.73	<85.6	19700	<174	40100
F4B-LD-504	504	1.79	2.49	3900	76100	4.45	6970	136000	3.50	3.91	<83.6	23200	<149	41400
F4B-FD-CP	Feed Displacement	1	2.28	3160	68600	2.28	3160	68600	1.64	1.81	100	17600	100	17600
F4B-EL-CP	Elution	1	27.3	145	1500	27.3	145	1500	<0.05	<0.05	<99.6	2440	<99.6	2440
Target	--	--	--	--	--	5.72	6690	137000	3.67	5.00	--	--	0	40800

Table B.31. Column F5 Test Analytical Data (T = 55°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
F5-LD-00	0	1	2.19	2560	94900	2.19	2560	94900	1.56	1.71	47900	17800	47900	17800
F5-LD-06	6	1	1.69	2380	90600	1.69	2380	90600	1.50	1.65	47100	17100	47100	17100
F5-LD-12	12	1	1.48	2580	93200	1.48	2580	93200	1.50	1.64	46300	17100	46300	17100
F5-LD-18	18	1	1.33	2540	92300	1.33	2540	92300	1.50	1.64	47100	17300	47100	17300
F5-LD-24	24	1	1.20	2440	92700	1.20	2440	92700	1.50	1.65	46500	17200	46500	17200
F5-LD-36	36	1	0.981	2480	82900	0.981	2480	82900	1.49	1.64	45800	16900	45800	16900
F5-LD-48	48	1	0.899	2610	91100	0.899	2610	91100	1.50	1.65	45800	16800	45800	16800
F5-LD-60	60	1	0.784	2510	91000	0.784	2510	91000	1.50	1.65	46600	17000	46600	17000
F5-LD-80	80	1	0.669	2420	90800	0.669	2420	90800	1.49	1.64	47100	17400	47100	17400
F5-LD-120	120	1	0.582	2400	92900	0.582	2400	92900	1.50	1.65	46200	17000	46200	17000
F5-LD-180	180	1	0.521	2520	91900	0.521	2520	91900	1.50	1.65	46700	17100	46700	17100
F5-LD-240	240	1	0.500	2530	90200	0.500	2530	90200	1.50	1.65	46900	17200	46900	17200
F5-LD-600	600	1	0.493	2500	92400	0.493	2500	92400	1.51	1.65	46400	17000	46400	17000
F5-FD-CP	Feed Displacement	1	0.386	1500	56500	0.386	1500	56500	0.953	1.04	26800	10100	26800	10100
F5-EL-CP	Elution	1	9.13	7.77	1420	9.13	7.77	1420	<0.05	<0.05	107	2370	107	2370
Target	--	--	--	--	--	2.63	2570	95000	1.55	2.01	--	--	48900	19300

Table B.32. Column G1 Test Analytical Data (T = 60°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
G1-LD-00	0	1	2.08	2490	91200	2.08	2490	91200	1.55	1.70	48200	17600	48200	17600
G1-LD-06	6	1	1.84	2400	89700	1.84	2400	89700	1.51	1.65	47100	17400	47100	17400
G1-LD-12	12	1	1.67	2430	89400	1.67	2430	89400	1.51	1.65	47500	17400	47500	17400
G1-LD-18	18	1	1.49	2400	90600	1.49	2400	90600	1.50	1.64	47000	17200	47000	17200
G1-LD-24	24	1	1.36	2390	89700	1.36	2390	89700	1.50	1.65	46600	17100	46600	17100
G1-LD-36	36	1	1.15	2440	88200	1.15	2440	88200	1.50	1.64	46700	17200	46700	17200
G1-LD-48	48	1	0.980	2430	91300	0.980	2430	91300	1.51	1.65	46900	17200	46900	17200
G1-LD-60	60	1	0.836	2350	90500	0.836	2350	90500	1.50	1.64	46900	17100	46900	17100
G1-LD-80	80	1	0.677	2440	91100	0.677	2440	91100	1.50	1.64	46300	17000	46300	17000
G1-LD-120	120	1	0.483	2410	89900	0.483	2410	89900	1.50	1.64	47700	17500	47700	17500
G1-LD-180	180	1	0.351	2360	88300	0.351	2360	88300	1.50	1.65	47200	17300	47200	17300
G1-LD-240	240	1	0.309	2440	91000	0.309	2440	91000	1.50	1.64	46800	17200	46800	17200
G1-LD-600	600	1	0.253	2450	88800	0.253	2450	88800	1.51	1.66	46600	17000	46600	17000
G1-FD-CP	Feed Displacement	1	0.189	1390	54300	0.189	1390	54300	0.907	0.989	25500	9560	25500	9560
G1-EL-CP	Elution	1	7.32	2.64	1170	7.32	2.64	1170	<0.05	<0.05	<98.0	2360	<98.0	2360
Target	--	--	--	--	--	2.63	2570	95000	1.55	2.01	--	--	48900	19300

Table B.33. Column G2 Test Analytical Data (T = 60°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
G2-LD-00	0	1.67	1.90	1600	81300	3.17	2670	136000	1.63	1.79	<83.5	35300	<140	59000
G2-LD-06	6	1.96	1.41	1350	66200	2.76	2640	130000	1.54	1.69	<86.1	28600	<169	56000
G2-LD-12	12	1.87	1.38	1440	69800	2.58	2690	130000	1.55	1.70	<85.5	30100	<160	56200
G2-LD-18	18	2.04	1.20	1290	64300	2.45	2630	131000	1.53	1.68	<86.8	27400	<177	56000
G2-LD-24	24	1.92	1.21	1400	68400	2.32	2680	131000	1.57	1.72	<86.4	29500	<166	56600
G2-LD-36	36	1.85	1.13	1450	70000	2.10	2690	130000	1.56	1.73	<84.0	30600	<156	56700
G2-LD-48	48	1.92	1.14	1470	70900	2.19	2820	136000	1.55	1.70	<85.8	29500	<165	56600
G2-LD-60	60	1.93	0.944	1380	67400	1.83	2670	130000	1.53	1.69	<86.7	28600	<168	55300
G2-LD-80	80	2.00	0.817	1270	63600	1.63	2540	127000	1.53	1.69	<86.8	28000	<173	55900
G2-LD-120	120	1.92	0.756	1360	67000	1.46	2620	129000	1.56	1.71	<86.2	29000	<166	55800
G2-LD-180	180	1.89	0.655	1410	68800	1.24	2670	130000	1.54	1.70	<85.8	29400	<162	55600
G2-LD-240	240	1.91	0.626	1370	68800	1.19	2610	131000	1.55	1.70	<85.9	29600	<164	56400
G2-LD-600	600	1.82	0.543	1520	72400	0.987	2760	132000	1.58	1.55	<84.9	31300	<154	56900
G2-FD-CP	Feed Displacement	1	0.898	2070	102000	0.898	2070	102000	1.36	1.48	102	43300	102	43300
G2-EL-CP	Elution	1	8.75	4.36	1470	8.75	4.36	1470	<0.05	<0.05	<101	2340	<101	2340
Target	--	--	--	--	--	2.81	2720	134000	1.86	2.41	--	--	0	61200

Table B.34. Column G3 Test Analytical Data (T = 60°C, Flow rate = 7.08 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
G3-LD-00	0	1.66	1.94	1670	80100	3.22	2770	133000	1.63	1.81	<82.2	35700	<136	59200
G3-LD-06	6	1.79	1.62	1470	71700	2.89	2620	128000	1.56	1.72	<83.5	31500	<149	56300
G3-LD-12	12	1.78	1.54	1490	73500	2.74	2650	131000	1.58	1.73	<83.3	32000	<148	56900
G3-LD-18	18	1.74	1.46	1500	73900	2.54	2620	129000	1.58	1.73	<83.2	32100	<145	56000
G3-LD-24	24	1.77	1.36	1540	73000	2.41	2730	129000	1.57	1.73	<84.3	31900	<149	56500
G3-LD-36	36	1.79	1.24	1510	72400	2.22	2710	130000	1.55	1.71	<83.8	31200	<150	56000
G3-LD-48	48	1.87	1.11	1450	69100	2.07	2710	129000	1.55	1.70	<84.9	30100	<159	56300
G3-LD-60	60	1.81	1.08	1540	72400	1.95	2780	131000	1.58	1.73	<83.8	31300	<152	56600
G3-LD-80	80	1.83	0.981	1470	71900	1.79	2690	131000	1.57	1.72	<83.9	30400	<153	55600
G3-LD-120	120	1.83	0.827	1460	70600	1.51	2670	129000	1.58	1.73	<84.0	30900	<154	56600
G3-LD-180	180	1.80	0.759	1480	72000	1.37	2670	130000	1.57	1.73	<83.5	31500	<151	56800
G3-LD-240	240	1.76	0.712	1520	72400	1.25	2680	127000	1.56	1.71	<83.8	32000	<148	56300
G3-LD-600	600	1.88	0.591	1500	69900	1.11	2820	132000	1.57	1.73	<84.5	30000	<159	56500
G3-FD-CP	Feed Displacement	1	1.10	2080	102000	1.10	2080	102000	1.39	1.52	99.0	44800	99.0	44800
G3-EL-CP	Elution	1	8.32	4.17	1410	8.32	4.17	1410	<0.05	<0.05	<98.8	2350	<98.8	2350
Target	--	--	--	--	--	2.81	2720	134000	1.86	2.41	--	--	0	61200

Table B.35. Column G4 Test Analytical Data (T = 60°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
G4-LD-00	0	1.87	3.51	3660	72500	6.56	6840	135000	3.20	3.59	<84.7	20400	<158	38100
G4-LD-06	6	1.79	3.24	3800	74800	5.79	6796	134000	3.17	3.51	<86.7	20500	<155	36700
G4-LD-12	12	1.85	2.80	3600	71200	5.17	6642	131000	3.16	3.51	<88.7	20200	<164	37300
G4-LD-18	18	1.83	2.56	3530	70300	4.67	6444	128000	3.12	3.49	<85.0	20100	<155	37000
G4-LD-24	24	1.99	2.23	3360	67200	4.45	6698	134000	3.09	3.45	<86.5	18300	<172	36500
G4-LD-36	36	1.84	2.20	3580	72300	4.04	6570	133000	3.14	3.49	<85.5	20000	<157	36700
G4-LD-48	48	1.91	1.94	3340	69000	3.70	6363	131000	3.14	3.49	<85.8	19400	<164	37000
G4-LD-60	60	1.92	1.75	3400	68600	3.37	6544	132000	3.12	3.46	<98.2	19100	<189	36800
G4-LD-80	80	1.90	1.54	3260	67900	2.93	6204	129000	3.08	3.44	<85.8	19000	<163	36200
G4-LD-120	120	1.96	1.37	3490	68400	2.68	6834	134000	3.13	3.49	<85.9	19000	<168	37200
G4-LD-180	180	1.89	1.18	3480	69500	2.23	6574	131000	3.12	3.46	<85.9	19500	<162	36800
G4-LD-240	240	1.87	1.11	3480	70800	2.07	6499	132000	3.10	3.45	<85.3	19800	<159	37000
G4-LD-600	600	1.76	1.04	3720	76300	1.83	6557	134000	3.21	3.58	<84.5	21300	<149	37500
G4-FD-CP	Feed Displacement	1	1.62	4720	92900	1.62	4720	92900	2.38	2.65	<85.3	26200	<85.3	26200
Target	--	--	--	--	--	5.72	6690	137000	3.67	5.00	--	--	0	40800

Table B.36. Column G4B Test Analytical Data (T = 60°C, Flow rate = 0.08 mL/min)

Sample ID	Loading Time (hrs)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
G4B-LD-00	0	1.86	3.61	3940	75200	6.72	7330	140000	3.26	3.63	<85.2	20800	<159	38700
G4B-LD-04	4	1.85	3.47	3770	72800	6.43	6983	135000	3.15	3.50	<85.9	19900	<159	36900
G4B-LD-08	8	1.82	3.69	3840	75700	6.71	6984	138000	3.18	3.53	<85.5	20700	<156	37700
G4B-LD-12	12	1.85	3.21	3700	71100	5.92	6828	131000	3.17	3.54	<85.2	20700	<157	38200
G4B-LD-24	24	1.74	3.16	4080	77400	5.49	7088	134000	3.23	3.60	<84.2	22100	<146	38400
G4B-LD-72	72	1.84	2.55	3870	73200	4.70	7132	135000	3.24	3.63	<84.7	21000	<156	38700
G4B-LD-120	120	1.81	2.60	4060	77400	4.70	7346	140000	3.35	3.75	<84.2	22100	<152	40000
G4B-LD-168	168	1.89	2.36	3890	74600	4.45	7341	141000	3.42	3.81	<84.6	21700	<160	41000
G4B-LD-336	336	2.05	2.37	3820	73800	4.87	7842	152000	3.53	3.96	<85.0	20900	<175	42900
G4B-FD-CP	Feed Displacement	1	2.68	3080	74800	2.68	3080	74800	1.63	1.82	144	23300	144	23300
G4B-EL-CP	Elution	1	22.4	251	1900	22.4	251	1900	<0.05	<0.05	<100	2420	<100	2420
Target	--	--	--	--	--	5.72	6690	137000	3.67	5.00	--	--	0	40800

Table B.37. Column G5 Test Analytical Data (T = 60°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
G5-LD-00	0	1	2.22	2770	93600	2.22	2770	93600	1.55	1.70	47500	17600	47500	17600
G5-LD-06	6	1	1.82	2610	89100	1.82	2610	89100	1.49	1.64	46200	17100	46200	17100
G5-LD-12	12	1	1.59	2660	90300	1.59	2660	90300	1.49	1.63	46500	17100	46500	17100
G5-LD-18	18	1	1.43	2600	87900	1.43	2600	87900	1.49	1.64	46500	17100	46500	17100
G5-LD-24	24	1	1.37	2670	90500	1.37	2670	90500	1.50	1.64	46400	17100	46400	17100
G5-LD-36	36	1	1.23	2610	88000	1.23	2610	88000	1.49	1.64	46400	17000	46400	17000
G5-LD-48	48	1	1.14	2670	90700	1.14	2670	90700	1.50	1.64	46700	17000	46700	17000
G5-LD-60	60	1	1.05	2630	89700	1.05	2630	89700	1.50	1.64	46300	17000	46300	17000
G5-LD-80	80	1	1.04	2760	93900	1.04	2760	93900	1.49	1.64	45300	16700	45300	16700
G5-LD-120	120	1	0.979	2710	91300	0.979	2710	91300	1.49	1.64	45500	16700	45500	16700
G5-LD-180	180	1	0.954	2660	89900	0.954	2660	89900	1.49	1.64	46300	16900	46300	16900
G5-LD-240	240	1	0.946	2690	91400	0.946	2690	91400	1.50	1.64	46400	17000	46400	17000
G5-LD-600	600	1	1.01	2610	88900	1.01	2610	88900	1.50	1.65	45800	16900	45800	16900
G5-FD-CP	Feed Displacement	1	0.847	1860	65700	0.847	1860	65700	1.06	1.16	30100	11600	30100	11600
G5-EL-CP	Elution	1	12.2	32.3	1700	12.2	32.3	1700	<0.05	<0.05	112	2330	112	2330
Target	--	--	--	--	--	2.63	2570	95000	1.55	2.01	--	--	48900	19300

Table B.38. Column O1 Test Analytical Data (T = 45°C, Flow rate = 10.62 mL/min)

Sample ID	Loading Time (min)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	TIC (corr.) (mg/L)	TOC (corr.) (mg/L)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
Before Filter	--	--	--	--	--	--	--	--	--	--	25.8	55700	--	--
After Filter	--	--	--	--	--	--	--	--	--	--	63.4	51350	--	--
O1-LD-00	0	1	2.95	2770	97600	2.95	2770	97600	1.56	1.71	69.0	43800	54800	19700
O1-LD-06	6	1	2.57	2660	93700	2.57	2660	93700	1.50	1.67	83.7	45900	53900	19300
O1-LD-12	12	1	2.50	2630	95500	2.50	2630	95500	1.49	1.65	65.2	46150	53100	19200
O1-LD-18	18	1	2.37	2640	94300	2.37	2640	94300	1.52	1.68	66.1	46150	53200	19200
O1-LD-24	24	1	2.27	2610	93400	2.27	2610	93400	1.51	1.67	100	43550	53300	19300
O1-LD-36	36	1	2.22	2660	95000	2.22	2660	95000	1.49	1.66	91.8	45550	52500	19000
O1-LD-48	48	1	2.12	2520	94300	2.12	2520	94300	1.49	1.66	108	45800	52500	19000
O1-LD-60	60	1	2.04	2600	94200	2.04	2600	94200	1.49	1.65	65.9	45200	52700	19000
O1-LD-80	80	1	1.98	2580	95300	1.98	2580	95300	1.51	1.67	69.9	45800	53200	19100
O1-LD-120	120	1	1.61	2770	94500	1.61	2770	94500	1.49	1.66	93.6	45200	53100	19100
O1-LD-180	180	1	0.999	2730	95300	0.999	2730	95300	1.51	1.67	74.1	44700	52300	18800
O1-LD-240	240	1	0.745	2530	94800	0.745	2530	94800	1.50	1.66	91.0	44800	52800	19000
O1-LD-600	600	1	0.420	2770	96900	0.420	2770	96900	1.53	1.68	70.0	44900	52800	19100
O1-FD-CP	Feed Displacement	1	0.299	1810	66100	0.299	1810	66100	1.04	1.14	70.0	28700	35300	12600
O1-EL-CP	Elution	1	9.48	4.50	1390	9.48	4.50	1390	<0.05	<0.05	<10.0	170	113	2480
Target	--	--	--	--	--	2.63	2570	95000	1.55	2.01	--	--	48900	19300

Table B.39. Aging Batch Test Analytical Data

Sample ID	Loading Time (hrs)	Dilution Factor	Cs (raw) (mg/kg)	Al (raw) (mg/kg)	Na (raw) (mg/kg)	Cs (corr.) (mg/kg)	Al (corr.) (mg/kg)	Na (corr.) (mg/kg)	OH-Free (corr.) (meq/mL)	OH-Total (corr.) (meq/mL)	Cl (raw) (mg/kg)	NO_3 (raw) (mg/kg)	Cl (corr.) (mg/kg)	NO_3 (corr.) (mg/kg)
Test-25-A-0	0	1	3.90	2650	96300	3.90	2650	96300	1.54	1.68	50200	18000	50200	18000
Test-25-A-1	1	1	1.58	2590	93900	1.58	2590	93900	1.54	1.68	50600	18100	50600	18100
Test-25-A-4	4	1	0.373	2620	95600	0.373	2620	95600	1.51	1.66	49700	17800	49700	17800
Test-25-A-10	10	1	0.272	2550	94300	0.272	2550	94300	1.52	1.67	50900	18200	50900	18200
Test-25-A-24	24	1	0.271	2600	94800	0.271	2600	94800	1.50	1.65	49800	17900	49800	17900
Test-25-B-0	0	1	3.90	2650	96300	3.90	2650	96300	1.54	1.68	50200	18000	50200	18000
Test-25-B-1	1	1	1.58	2550	94300	1.58	2550	94300	1.50	1.66	50000	18000	50000	18000
Test-25-B-4	4	1	0.379	2510	95100	0.379	2510	95100	1.51	1.65	49800	17900	49800	17900
Test-25-B-10	10	1	0.288	2570	94300	0.288	2570	94300	1.53	1.67	50300	18000	50300	18000
Test-25-B-24	24	1	0.269	2590	93400	0.269	2590	93400	1.51	1.66	50200	18000	50200	18000
Test-25-C-0	0	1	3.90	2650	96300	3.90	2650	96300	1.54	1.68	50200	18000	50200	18000
Test-25-C-1	1	1	1.66	2440	94300	1.66	2440	94300	1.50	1.65	49800	17900	49800	17900
Test-25-C-4	4	1	0.408	2550	93200	0.408	2550	93200	1.49	1.65	49900	17900	49900	17900
Test-25-C-10	10	1	0.309	2490	93900	0.309	2490	93900	1.50	1.65	50100	18000	50100	18000
Test-25-C-24	24	1	0.337	2590	94100	0.337	2590	94100	1.49	1.65	49900	17900	49900	17900
Test-25-D-0	0	1	3.90	2650	96300	3.90	2650	96300	1.54	1.68	50200	18000	50200	18000
Test-25-D-1	1	1	1.63	2540	92900	1.63	2540	92900	1.51	1.66	50200	17900	50200	17900
Test-25-D-4	4	1	0.460	2480	94700	0.460	2480	94700	1.51	1.66	50200	17900	50200	17900
Test-25-D-10	10	1	0.292	2530	93900	0.292	2530	93900	1.51	1.66	50300	18000	50300	18000
Test-25-D-24	24	1	0.318	2510	94700	0.318	2510	94700	1.51	1.66	49900	17800	49900	17800
Test-45-A-0	0	1	3.90	2650	96300	3.90	2650	96300	1.54	1.68	50200	18000	50200	18000
Test-45-A-1	1	1	2.01	2580	95400	2.01	2580	95400	1.51	1.65	48800	17500	48800	17500
Test-45-A-4	4	1	1.09	2510	94000	1.09	2510	94000	1.50	1.65	48800	17500	48800	17500
Test-45-A-10	10	1	1.11	2490	94400	1.11	2490	94400	1.50	1.65	48800	17500	48800	17500
Test-45-A-24	24	1	0.611	2450	92200	0.611	2450	92200	1.47	1.62	48200	17300	48200	17300
Test-45-B-0	0	1	3.90	2650	96300	3.90	2650	96300	1.54	1.68	50200	18000	50200	18000
Test-45-B-1	1	1	2.12	2600	94700	2.12	2600	94700	1.49	1.65	49300	17700	49300	17700
Test-45-B-4	4	1	0.732	2580	95900	0.732	2580	95900	1.52	1.66	49400	17700	49400	17700
Test-45-B-10	10	1	0.911	2490	94000	0.911	2490	94000	1.51	1.66	49000	17500	49000	17500
Test-45-B-24	24	1	1.16	2550	94200	1.16	2550	94200	1.50	1.65	48900	17500	48900	17500
Target	--	--	--	--	--	2.63	2570	95000	1.55	2.01	--	--	48900	19300

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