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Cesium Isotherm Testing with Spherical Resorcinol-Formaldehyde Resin at High Sodium Concentrations

April 2016

RL Russell
SK Fiskum
MR Smoot
DE Rinehart

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Executive Summary

Washington River Protection Solutions (WRPS) is developing a Low-Activity Waste Pretreatment System (LAWPS) to provide low-activity waste (LAW) directly to the Hanford Tank Waste Treatment and Immobilization Plant (WTP) Low-Activity Waste Vitrification Facility for immobilization. The pretreatment that will be conducted on tank waste supernate at the LAWPS facility entails filtration to remove entrained solids and cesium (Cs) ion exchange to remove Cs from the product sent to the WTP. Currently, spherical resorcinol-formaldehyde (sRF) resin (Microbeads AS, Skedsmokorset, Norway) is the Cs ion exchange resin of choice. Most work on Cs ion exchange efficacy in Hanford tank waste has been conducted at nominally 5 M sodium (Na) supernatant. WRPS is examining the possibility of processing supernatant at high Na concentrations—up to 8 M Na—to maximize processing efficiency through the LAWPS. Minimal Cs ion exchange work has been conducted at 6 M and 8 M Na supernatant concentrations.

WRPS contracted the Pacific Northwest National Laboratory (PNNL) to develop, in accordance with a WRPS-approved Test Plan(1), Cs isotherms(2) at 6.5 and 8.0 M Na supernatant concentrations with sRF resin, Lot 1F-370/1392, which was produced by Microbeads AS in August 2011. PNNL tested five initial Cs concentrations (i.e., 5.0×10^{-6} M, 5.0×10^{-5} M, 5.0×10^{-4} M, 5.0×10^{-3} M, and 5.0×10^{-2} M Cs) to show the impacts and interdependencies of Cs loading onto the sRF resin in a matrix of the following initial conditions:

- 6.5 and 8 M Na
- 0, 0.035, 0.35, and 0.5 M potassium (K)
- 0.1 and 1 M free hydroxide (OH^-)
- 25, 35, and 50 °C.

In addition, a small subset of contacts was tested at 5 M Na, 1.0 M OH, three K concentrations, and four Cs concentrations to replicate previous test matrix conditions at the current test conditions for comparisons.

Numerous isotherms were developed from 336 batch contacts of small amounts of sRF H-form resin with a simple simulant (nominally 0.25 g of dry H-form resin with nominally 25 mL of simulant) contacted under inert nitrogen cover gas for 72 hours (to assure equilibrium conditions). The simulant was analyzed before and after batch contact for Na, K, Cs, OH, density, and water content. The Cs results were used to assess the Cs isotherms.

The following conclusions were developed from the isotherm testing:

- Efficacy: Tie back to previous data with the 5 M Na matrix conditions showed that the sRF had maintained its effectiveness since production and storage (5 years aging).
- Sodium Effect: Cs loading is virtually identical between 6.5 and 8 M Na at low Cs concentrations and slightly enhanced at 6.5 M Na and high Cs concentrations.
- Potassium Effect: The K effect varies with Cs concentrations. As K concentration increases, Cs loading decreases. However, the K effect diminishes as the Cs concentration increases, essentially resulting in convergence of isotherms at the highest Cs concentration tested.

(1) TP-SRFBC-001, *sRF Resin Batch Contact Testing FY 2016*, SK Fiskum, August 31, 2015 (not publicly available).
(2) Isotherms are graphical representations of the Cs loading capacity on ion exchange media as a function of equilibrium Cs concentration.

- Hydroxide Effect: The equilibrium OH in this test was nominally 0.03 and 0.91 M (from the neutralization of feed matrix OH with the H-form resin). The effect of OH on Cs loading is slightly larger at higher Na levels. The more OH present, the more of a positive effect on the Cs loading is seen.
- Temperature Effect: At both 6.5 and 8 M Na, increasing temperature decreases Cs load capacity, regardless of K and OH concentrations. The depression at 8 M Na is slightly enhanced relative to the 6.5 M Na matrix.

Acknowledgments

The authors gratefully acknowledge the efforts of Dr. Garrett Brown in his thorough technical review of the data; Mr. Matt Landon, Mr. Kevin Ard, and Dr. Clark Carlson for their consulting during the course of the testing; Mr. Bill Dey for quality assurance and quality control reviews; and Mr. Mike Parker for his efforts in technically editing this document.

Acronyms and Abbreviations

DOE	U.S. Department of Energy
ILAW	immobilized low-activity waste
LAW	low-activity waste
LAWPS	Low-Activity Waste Pretreatment System
PNNL	Pacific Northwest National Laboratory
QA	quality assurance
R&D	research and development
RF	resorcinol formaldehyde
RV	resin volume
sRF	spherical resorcinol-formaldehyde (resin)
SwRI	Southwest Research Institute
TI	test instruction
WRPS	Washington River Protection Solutions
WTP	Hanford Tank Waste Treatment and Immobilization Plant
WWFTP	WRPS Waste Form Testing Program

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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 waste consists of insoluble sludge, saltcake, and supernate and is stored in underground waste tanks. The supernates are complex mixtures 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, primarily ^{137}Cs. The Low-Activity Waste Pretreatment System (LAWPS) project provides for the early production of immobilized low-activity waste (ILAW) by feeding low-activity waste (LAW) directly from Tank Farms to the Hanford Tank Waste Treatment and Immobilization Plant (WTP) LAW Vitrification Facility for immobilization. Prior to the transfer of feed to the WTP LAW Vitrification Facility, tank supernatant waste is intended to be pretreated in the LAWPS to meet the WTP LAW acceptance criteria. The key process operations for treating the waste include solids filtration and cesium (Cs) removal. Current planning requires the solids filtration activity be accomplished by the use of cross-flow filtration and the Cs removal be accomplished through the use of spherical resorcinol-formaldehyde (sRF) ion exchange resin.

Tasks related to technology maturation of the sRF resin are identified in RPP-PLAN-57181, *Technology Maturation Plan for the Low-Activity Waste Pretreatment System Project* (Ard 2014). One of those tasks (i.e., sRF-3) includes obtaining data on expanded isotherm testing above 6 M sodium (Na). Expanded isotherm testing was identified by the LAWPS project, during planning meetings, to aid in the optimization efficiency to be performed for waste concentrations up to 8 M Na. In addition, extending the Na range to 8 M may allow for increasing the waste acceptance criteria as described in RPP-RPT-58649, *Waste Acceptance Criteria for the Low Activity Waste Pretreatment System* (Reynolds 2015).

Test data for sRF batch distribution exist for Na concentrations ranging from 0.1 to 6.26 M and with potassium (K) concentrations ranging from 0 to 0.75 M (Russell et al. 2014; King et al. 2004; Nash and Isom 2010; Nash et al. 2006; Fiskum et al. 2004; Dwivedi et al. 2013). Test data for sRF small column testing exist for Na concentrations ranging from 2 to 8 M and with K concentrations ranging from 0 to 0.03 M (Russell et al. 2014; Russell et al. 2012). In addition, testing using a variety of simulated and actual Hanford tank wastes was conducted with nominally 5 M Na matrix (Fiskum et al. 2006a; Fiskum et al. 2006b; Fiskum et al. 2006c; Fiskum et al. 2007; Nash et al. 2006). These existing data are expected to cover the nominal conditions to which the ion exchange resin will be exposed. As described above, additional data are needed for Na concentrations up to 8.0 M. These additional data for the higher Na concentrations may support future optimization efficiency at the LAWPS.

This work was conducted with funding from Washington River Protection Solutions (WRPS) under contract 36437-186, Expanded Isotherm Testing for sRF Resin. The work was conducted as part of Pacific Northwest National Laboratory (PNNL) Project 68072 in accordance to a client-approved test plan(1) and four test instructions (i.e., TI-SRFBC0002(2), TI-SRFBC-003(3), TI-SRFBC-004(4), and TI-SRFBC-005(5)). The purpose of the work described in this report is to develop a series of isotherms at

(1) TP-SRFBC-001, *sRF Resin Batch Contact Testing FY 2016*, SK Fiskum, August 31, 2015 (not publicly available).
(2) TI-SRFBC-002, *Simulant Preparation for Extended Isotherm Batch Contact Testing*, October 6, 2015 (not publicly available).
(3) TI-SRFBC-003. *sRF Expanded Batch Contact Loading Tests at 25 °C*. RL Russell, October 19, 2015 (not publicly available).
(4) TI-SRFBC-004. *sRF Expanded Batch Contact Loading Tests at 35 °C*. RL Russell, October 19, 2015 (not publicly available).
(5) TI-SRFBC-005. *sRF Expanded Batch Contact Loading Tests at 50 °C*. RL Russell, October 19, 2015 (not publicly available).

five Cs concentrations to show the impacts and interdependencies of Cs loading onto the sRF in a matrix with varying K, hydroxide (OH), and Na levels, and at three different temperatures.

This report is divided into sections as follows:

- Section 1.0 provides a brief introduction and details the basis of the PNNL Quality Assurance (QA) Program as applied to the WRPS quality requirements.
- Section 2.0 describes the test design, simplified simulant solution and sRF resin preparations, equipment, process steps, and chemical analyses.
- Section 3.0 provides a summary of the experimental isotherm data and includes discussions of the Na, K, and OH concentration and temperature effects on the Cs loading onto the sRF.
- Section 4.0 provides a discussion of the post-batch-contacted simulant solution properties inclusive of water content, simulant density, and OH concentration.
- Section 5.0 provides a list of conclusions and recommendations obtained from this experimental work.
- Section 6.0 provides the full reference list.
- Appendix A provides the simple simulant composition, as prepared.
- Appendix B lists the specific batch contact experimental conditions on a sample-by-sample basis.
- Appendix C provides the Na, Cs, K, and OH analytical data provided by Southwest Research Institute (SwRI) on the simulant feed and post-contacted solutions.
- Appendix D provides the isotherm data set summary inclusive of the sample identification (ID), equilibrium Cs concentration, and the calculated millimoles Cs per gram H-form resin.

1.1 Quality Assurance

All research and development (R&D) work at PNNL is performed in accordance with PNNL's laboratory-level Quality Management Program, which is based on a graded application of NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility Applications*, to R&D activities. In addition to the PNNL-wide QA controls, the QA controls of the WRPS Waste Form Testing Program (WWFTP) QA program were also implemented for the work. The WWFTP QA program consists of the WWFTP Quality Assurance Plan (QA-WWFTP-001) and associated QA-NSLW-numbered procedures that provide detailed instructions for implementing NQA-1 requirements for R&D work. The WWFTP QA program is based on the requirements of NQA-1-2008, *Quality Assurance Requirements for Nuclear Facility Applications*, and NQA-1a-2009, *Addenda to ASME NQA-1-2008 Quality Assurance Requirements for Nuclear Facility Applications*, graded on the approach presented in NQA-1-2008, Part IV, Subpart 4.2, "Guidance on Graded Application of Quality Assurance (QA) for Nuclear-Related Research and Development". Preparation of this report and performance of the associated experimental work were assigned the technology level "Applied Research" and were conducted in accordance with procedure QA-NSLW-1102, *Scientific Investigation for Applied Research*. All staff members contributing to the work have technical expertise in the subject matter and received QA training prior to performing quality-affecting work. The "Applied Research" technology level provides adequate controls to ensure that the activities were performed correctly. Use of both the PNNL-wide and WWFTP QA controls ensured that all client QA expectations were addressed in performing the work.

2.0 Experimental

This section describes the sRF test resin, resin preparation, simple simulant preparation, batch ion exchange processing conditions, and post-batch-contacted solution analysis. Experimental conditions and analytical data are provided in Appendix A and Appendix B, respectively.

2.1 Spherical RF Resin

The sRF resin used in these tests was prepared by Microbeads (Skedsmokorset, Norway), Lot Number 1F-370-1392 (sometimes referred to as 1F-370/1392) manufactured in August 2011. The resin had been stored as manufactured in the H-form in water under pressurized nitrogen gas (0.26 bar). These storage conditions were maintained in the storage container: a sealed Finncont(1) as shown in Figure 2.1. Because the resin is known to degrade on contact with oxygen from air, purging with inert gas is considered necessary. The oxidation-degradation is not a physical hazard, but it will damage active Cs exchange sites and thus reduce effectiveness as a Cs ion exchanger.

Figure 2.1. Finncont Containing sRF Resin

WRPS received the resin from the manufacturer in April 2015 and stored the Finncont in a climate-controlled area until transferring it to PNNL. The Finncont was received at PNNL on September 1, 2015. The internal pressure was recorded at 0.26 bar based on the Nuova FIMA gage installed on the Finncont on September 2, 2015. A ~1 L representative sample was removed from the Finncont on November 5, 2015 with the aid of vacuum transfer for use in the batch contact tests. After removal of the resin sample

(1) See http://www.finncont.com/index.php/en/products/tailored-active-container for a description of the vessel manufactured by FINNCONT Oy, Kiertotie 10-12, PL 44, 34801 VIRRAT Finland.

from the Finncont, the headspace in the Finncont was purged with nitrogen gas to remove the air (and oxygen) and left slightly pressurized at 0.155 bar. The headspace in the sample container was also purged with nitrogen gas to protect the resin from oxygen, but was not pressurized.

Figure 2.2 displays the retrieved resin sample and an example visible light microscopy image of the Lot Number 1F-370-1392 sRF resin after drying to a free-flowing form at 50 °C in a vacuum oven. The bead diameters (~0.44 mm) are similar to the bead diameters shown by Russell et al. (2014). The resin beads appear to be uniformly spherical. There is a color variation between beads: orange and brick red.

(a) (b)

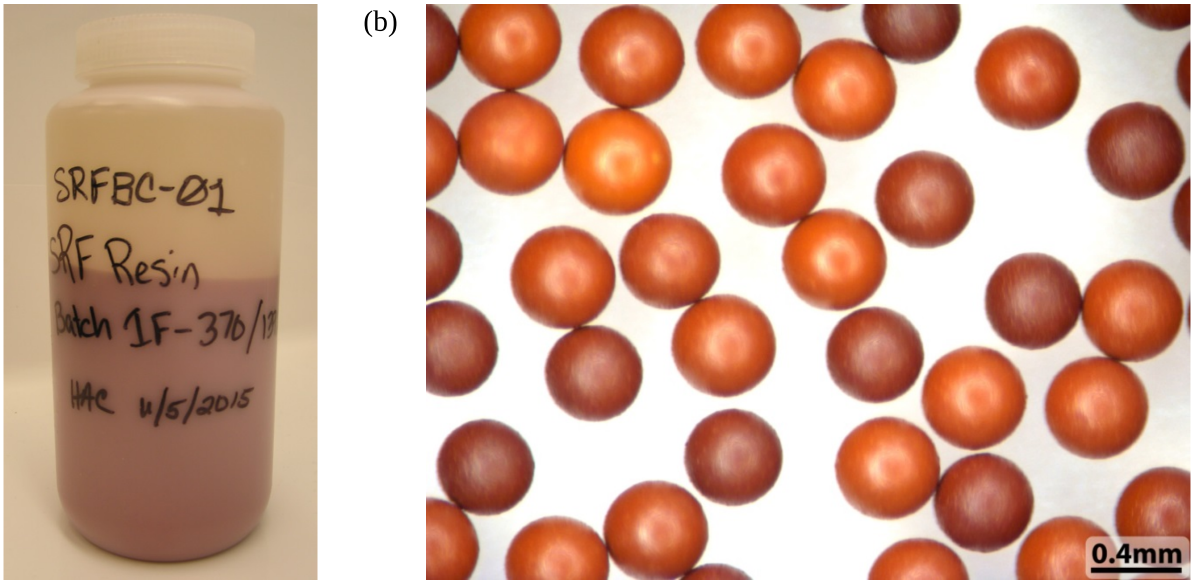


Figure 2.2. Spherical Resorcinol-Formaldehyde Resin Lot Number 1F-370-1392, H-form (a) Retrieved Sample and (b) Light Microscopy Image

2.2 Resin Pretreatment Processing

The resin was pretreated in two batches. The first batch of approximately 85 mL resin (H-form) was dispensed into a 100 mL graduated cylinder and allowed to settle to a constant volume during tapping/vibration. The resin was then transferred into a 1000 mL glass beaker. The second batch of approximately 246 mL resin (H-form) was dispensed into a 250 mL graduated cylinder and allowed to settle to a constant volume during tapping/vibration. The resin was then transferred into a 2000 mL glass beaker.

The overall resin bulk pretreatment steps are shown in Table 2.1 and are consistent with the resin pretreatment protocol(2) and previous testing (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. After the pretreatment of the resin was complete, it was stored in a sealed container under deionized (DI) water and the headspace purged with nitrogen to eliminate contact with oxygen.

(2) 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, Aiken, South Carolina.

Table 2.1. Ion Exchange Pretreatment Process Steps

Process/Pretreatment Step	Solution	Volume	Time	Mixing
	Bulk Pretreatment			
Water Rinse	DI Water	5 RV[(a)]	40 min	Swirl[(b)]
Resin Expansion	1 M NaOH	5 RV	1 h	Swirl
Resin Expansion	1 M NaOH	--	20 h	Soak
Water Rinse – 1st	DI Water	5 RV	30 min	Swirl
Water Rinse – 2nd	DI Water	5 RV	45 min	Swirl
Water Rinse – 3rd	DI Water	5 RV	30 min	Swirl
Resin Conversion	0.5 M HNO_3	10 RV	2 h	Swirl
Water Rinse – 4th	DI Water	6 RV	30 min	Swirl
Water Rinse – 5th	DI Water	6 RV	30 min	Swirl
Water Rinse – 6th	DI Water	6 RV	30 min	Swirl

(a) Resin volume (RV), original volume of resin subsample collected for pretreatment.
(b) Gently swirling by hand every 10 min.

2.3 Simulant Preparation and Analysis

A total of 92 aqueous non-radioactive simulant stock solutions were prepared for use in batch contact testing. The simulants were prepared stepwise by first preparing 19 ‘mother’ simulant solutions. The mother simulant solutions’ targeted concentrations for Na, K, and OH are shown in Figure 2.3. The ‘daughter’ simulants were prepared by spiking subsamples of the mother simulant with $CsNO_3$ at varying concentrations as shown in Figure 2.3 to achieve the 92 daughter simulant solutions.

The mother simulants were prepared by dissolving sodium nitrate ($NaNO_3$) and potassium nitrate (KNO_3) salts and adding 50% (w/w) sodium hydroxide (NaOH) and deionized water (18 MΩ resistivity). Solubility limitations of all nitrate solutions precluded achieving 8 M Na. Therefore, to achieve 8 M Na solutions for the mother simulants, sodium nitrite ($NaNO_2$) was used in addition to sodium nitrate and sodium hydroxide. Both sodium nitrate and sodium nitrite are expected to act as spectator anions with no effect on the Cs batch equilibrium. Note that the exclusion of other anions (aluminate, sulfate, etc.) from the simulant impacts the ionic strength of the solution; comparisons to other data should account for this difference. The complete simulant composition, inclusive of anions, is shown in Appendix A.

The 5 M Na matrix testing was limited in scope. It was intended to be a direct link to previously reported data (Russell et al. 2014, Fiskum et al. 2004, and Nash et al. 2006). The testing reported herein uses altered parameters relative to those used by Russell et al. (2014): resin lot, resin age, phase ratio, and inerting the batch contact vessel. Thus, should the isotherm results differ for the identical simulant matrix, the difference may be attributed to the altered test parameters.

Each of the 92 daughter simulants was tracked with identification such as 5-H-2-A.

- The first number represents the nominal Na concentration (i.e., 5 for 5 M Na, 6 for 6.5 M Na, and 8 for 8 M Na).
- The middle letter designates the hydroxide content (i.e., L for 0.1 M hydroxide and H for 1 M hydroxide).
- The middle digit signifies the K concentration (i.e., 1 for 0 M K, 2 for 0.005 M K, 3 for 0.035 M K, 4 for 0.05 M K, 5 for 0.35 M K and 6 for 0.5 M K).

- Finally the last letter is coded for the target Cs concentration (i.e., A for 5E-6 M Cs, B for 5E-5 M Cs, C for 5E-4 M Cs, D for 5E-3 M Cs, and E for 5E-2 M Cs).

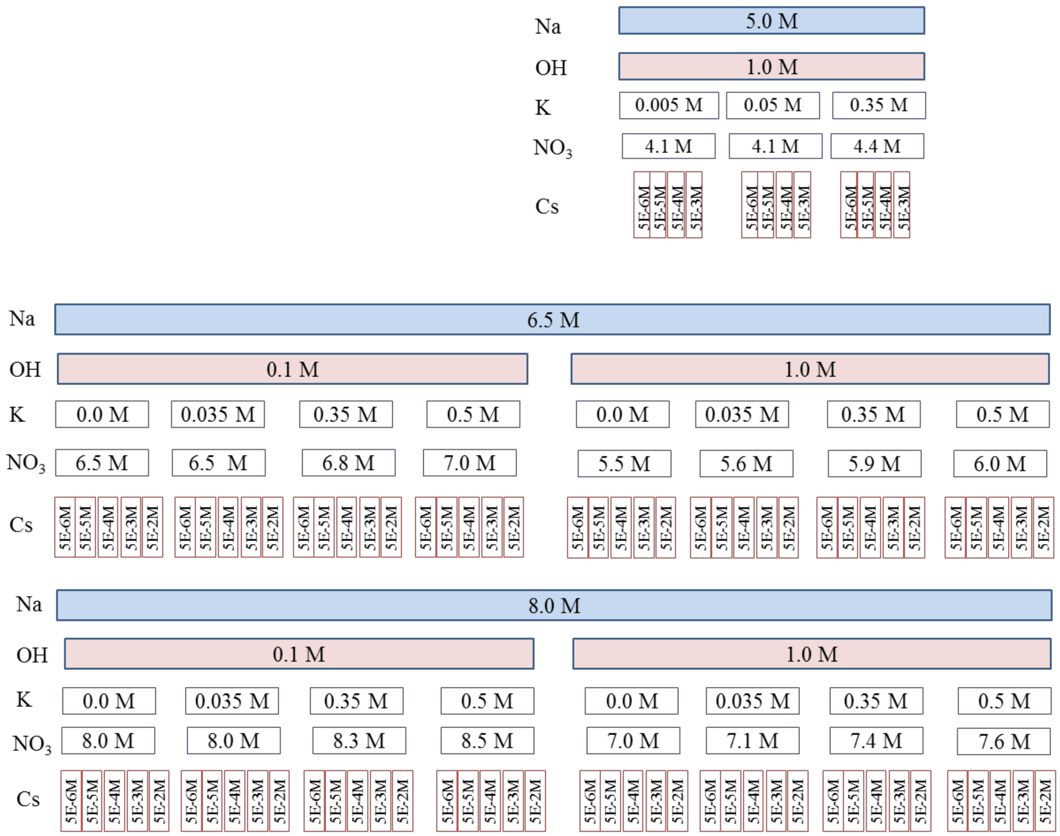


Figure 2.3. Targeted Concentrations for the Batch Contact Simulants

The density of each solution was determined from the net mass of a 100 or 250 mL sample in a volumetric flask. The reference temperature of the solutions during this process was 20 °C. The water content was determined by drying the 1 mL delivered volumes at 105 °C in a glass vial to constant mass. The initial mass (M_i) and final mass (M_f) were recorded and water content was calculated according to Equation 2.1.

$$\text{wt\% water} = \frac{(M_i - M_f)}{M_i} \times 100 \tag{2.1}$$

The solution sample identification, target analyte concentrations, density, and water content for each of the 92 daughter simulants are reported in Table 2.2.

All 92 daughter solutions were analyzed for Na, K, Cs, and free OH^- by SwRI. Sample aliquots were acid-digested with 50% hydrochloric acid and then were analyzed for Na and K by inductively coupled plasma optical emission spectroscopy according to U.S. Environmental Protection Agency (EPA) publication SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Method 6010C, “Inductively Coupled Plasma-Atomic Emission Spectrometry”, and for Cs by inductively coupled plasma mass spectrometry according to SW-846 Method 6020A, “Inductively Coupled Plasma-Mass Spectrometry”. A different aliquot was analyzed directly for free hydroxide by acid titration with potentiometric detection of the inflection point. Quality control sample results (e.g., blanks, duplicates, and spike recoveries), along with standard results for each analysis batch, are maintained in the PNNL project records and not reported herein.

In most cases the measured analyte concentrations were within 10% of the calculated as-prepared concentrations, confirming accuracy of the simulant preparation. In some cases, the analyzed concentration deviated more than 10% from the calculated concentration. The Na and K content in one simulant (6-L-5-E at 6.5 M Na) deviated by 10.2%. In the case of K analysis, the 5 M Na simulant with 0.005 M K had analysis values approximately 15-22% higher than calculated as prepared. In all cases, the 0 M K simulants had reportable K levels in the 10^{-4} M range, likely a contaminant in the Na salts. For the Cs analysis, four simulants (6-L-3-A, 8-L-1-D, 8-L-5-B, and 8-H-5-A) deviated >10% from the calculated as-prepared value. Table 2.3 lists each daughter simulant, its target Na and hydroxide concentrations, as-prepared concentrations for Na and hydroxide, analyzed concentrations for Na and hydroxide, and the relative percent difference (RPD) between as-prepared and analyzed for each analyte. Table 2.4 lists each daughter simulant, its target K and Cs concentrations, as-prepared concentrations for K and Cs, analyzed concentrations for K and Cs, and the RPD between as-prepared and analyzed for each analyte. For the purposes of batch contact sample data analysis, the measured analyte concentrations were used as the definitive feed analyte concentrations.

Table 2.2. Batch Contact Feed Simulants – Target Concentrations, Measured Density and Water Content

Simulant ID	Target Na Conc. (M)	Target OH Conc. (M)	Target K Conc. (M)	Target Cs Conc. (M)	Density (g/mL)	Water Content (%)
5-H-2-A	5	1	0.005	5 E-6	1.242	68.65
5-H-2-B	5	1	0.005	5 E-5	1.241	69.10
5-H-2-C	5	1	0.005	5 E-4	1.242	68.71
5-H-2-D	5	1	0.005	5 E-3	1.242	68.49
5-H-4-A	5	1	0.05	5 E-6	1.244	67.79
5-H-4-B	5	1	0.05	5 E-5	1.243	67.95
5-H-4-C	5	1	0.05	5 E-4	1.246	67.82
5-H-4-D	5	1	0.05	5 E-3	1.247	67.43
5-H-5-A	5	1	0.35	5 E-6	1.261	66.83
5-H-5-B	5	1	0.35	5 E-5	1.259	66.93
5-H-5-C	5	1	0.35	5 E-4	1.260	66.81
5-H-5-D	5	1	0.35	5 E-3	1.262	66.74
6-L-1-A	6.5	0.1	0	5 E-6	1.349	58.37
6-L-1-B	6.5	0.1	0	5 E-5	1.330	58.74
6-L-1-C	6.5	0.1	0	5 E-4	1.331	58.43
6-L-1-D	6.5	0.1	0	5 E-3	1.332	58.29
6-L-1-E	6.5	0.1	0	5 E-2	1.335	57.89
6-L-3-A	6.5	0.1	0.035	5 E-6	1.327	58.63
6-L-3-B	6.5	0.1	0.035	5 E-5	1.324	58.92
6-L-3-C	6.5	0.1	0.035	5 E-4	1.326	58.69
6-L-3-D	6.5	0.1	0.035	5 E-3	1.327	58.57
6-L-3-E	6.5	0.1	0.035	5 E-2	1.333	58.21
6-L-5-A	6.5	0.1	0.35	5 E-6	1.344	56.81
6-L-5-B	6.5	0.1	0.35	5 E-5	1.341	57.13
6-L-5-C	6.5	0.1	0.35	5 E-4	1.345	56.83
6-L-5-D	6.5	0.1	0.35	5 E-3	1.345	56.73
6-L-5-E	6.5	0.1	0.35	5 E-2	1.350	56.31
6-L-6-A	6.5	0.1	0.5	5 E-6	1.354	55.84
6-L-6-B	6.5	0.1	0.5	5 E-5	1.352	56.14
6-L-6-C	6.5	0.1	0.5	5 E-4	1.353	55.86
6-L-6-D	6.5	0.1	0.5	5 E-3	1.355	55.77
6-L-6-E	6.5	0.1	0.5	5 E-2	1.357	55.38

Table 2.2. (contd)

Simulant ID	**Target Na Conc. (M)**	**Target OH Conc. (M)**	**Target K Conc. (M)**	**Target Cs Conc. (M)**	**Density (g/mL)**	**Water Content (%)**
6-H-1-A	6.5	1	0	5 E-6	1.311	61.27
6-H-1-B	6.5	1	0	5 E-5	1.309	61.35
6-H-1-C	6.5	1	0	5 E-4	1.311	61.23
6-H-1-D	6.5	1	0	5 E-3	1.319	60.95
6-H-1-E	6.5	1	0	5 E-2	1.316	59.61
6-H-3-A	6.5	1	0.035	5 E-6	1.317	60.13
6-H-3-B	6.5	1	0.035	5 E-5	1.316	60.40
6-H-3-C	6.5	1	0.035	5 E-4	1.317	60.04
6-H-3-D	6.5	1	0.035	5 E-3	1.318	59.63
6-H-3-E	6.5	1	0.035	5 E-2	1.323	58.78
6-H-5-A	6.5	1	0.35	5 E-6	1.332	58.90
6-H-5-B	6.5	1	0.35	5 E-5	1.329	58.89
6-H-5-C	6.5	1	0.35	5 E-4	1.333	58.89
6-H-5-D	6.5	1	0.35	5 E-3	1.334	58.88
6-H-5-E	6.5	1	0.35	5 E-2	1.339	58.43
6-H-6-A	6.5	1	0.5	5 E-6	1.340	57.92
6-H-6-B	6.5	1	0.5	5 E-5	1.336	58.38
6-H-6-C	6.5	1	0.5	5 E-4	1.339	58.14
6-H-6-D	6.5	1	0.5	5 E-3	1.341	58.06
6-H-6-E	6.5	1	0.5	5 E-2	1.344	58.59
8-L-1-A	8	0.1	0	5 E-6	1.377	53.59
8-L-1-B	8	0.1	0	5 E-5	1.375	53.84
8-L-1-C	8	0.1	0	5 E-4	1.375	53.60
8-L-1-D	8	0.1	0	5 E-3	1.377	53.48
8-L-1-E	8	0.1	0	5 E-2	1.382	53.17
8-L-3-A	8	0.1	0.035	5 E-6	1.376	53.39
8-L-3-B	8	0.1	0.035	5 E-5	1.375	53.67
8-L-3-C	8	0.1	0.035	5 E-4	1.378	53.35
8-L-3-D	8	0.1	0.035	5 E-3	1.376	53.23
8-L-3-E	8	0.1	0.035	5 E-2	1.380	52.97
8-L-5-A	8	0.1	0.35	5 E-6	1.395	51.66
8-L-5-B	8	0.1	0.35	5 E-5	1.391	51.91
8-L-5-C	8	0.1	0.35	5 E-4	1.393	51.66
8-L-5-D	8	0.1	0.35	5 E-3	1.393	51.52
8-L-5-E	8	0.1	0.35	5 E-2	1.399	51.20
8-L-6-A	8	0.1	0.5	5 E-6	1.402	50.73
8-L-6-B	8	0.1	0.5	5 E-5	1.401	50.98
8-L-6-C	8	0.1	0.5	5 E-4	1.402	50.68
8-L-6-D	8	0.1	0.5	5 E-3	1.402	50.66
8-L-6-E	8	0.1	0.5	5 E-2	1.410	50.37
8-H-1-A	8	1	0	5 E-6	1.360	55.96
8-H-1-B	8	1	0	5 E-5	1.357	56.12
8-H-1-C	8	1	0	5 E-4	1.359	55.86
8-H-1-D	8	1	0	5 E-3	1.362	55.71
8-H-1-E	8	1	0	5 E-2	1.368	55.37

Table 2.2. (contd)

Simulant ID	Target Na Conc. (M)	Target OH Conc. (M)	Target K Conc. (M)	Target Cs Conc. (M)	Density (g/mL)	Water Content (%)
8-H-3-A	8	1	0.035	5 E-6	1.365	55.42
8-H-3-B	8	1	0.035	5 E-5	1.362	55.59
8-H-3-C	8	1	0.035	5 E-4	1.364	55.46
8-H-3-D	8	1	0.035	5 E-3	1.364	55.31
8-H-3-E	8	1	0.035	5 E-2	1.367	55.00
8-H-5-A	8	1	0.35	5 E-6	1.384	53.67
8-H-5-B	8	1	0.35	5 E-5	1.380	53.91
8-H-5-C	8	1	0.35	5 E-4	1.381	53.69
8-H-5-D	8	1	0.35	5 E-3	1.383	53.54
8-H-5-E	8	1	0.35	5 E-2	1.385	53.17
8-H-6-A	8	1	0.5	5 E-6	1.389	52.81
8-H-6-B	8	1	0.5	5 E-5	1.386	53.13
8-H-6-C	8	1	0.5	5 E-4	1.388	52.87
8-H-6-D	8	1	0.5	5 E-3	1.390	52.75
8-H-6-E	8	1	0.5	5 E-2	1.395	52.35

Table 2.3. Batch Contact Feed Simulants – Sodium and Hydroxide Contents

	Na Concentration (M)				OH Concentration (M)			
Simulant ID	Target	As Prepared	Analyzed	RPD (%)	Target	As Prepared	Analyzed	RPD (%)
5-H-2-A	5	4.95	4.96	-0.23	1	0.986	1.01	-2.40
5-H-2-B	5	4.90	4.83	1.52	1	0.977	0.990	-1.28
5-H-2-C	5	4.94	4.87	1.43	1	0.985	0.995	-0.98
5-H-2-D	5	4.95	4.92	0.75	1	0.987	1.00	-1.28
5-H-4-A	5	4.99	4.92	1.53	1	0.994	1.01	-1.66
5-H-4-B	5	4.95	4.87	1.51	1	0.985	1.02	-3.60
5-H-4-C	5	4.99	4.83	3.18	1	0.993	1.01	-1.76
5-H-4-D	5	5.00	4.87	2.50	1	0.994	1.00	-0.55
5-H-5-A	5	4.97	4.92	1.16	1	0.992	1.01	-1.83
5-H-5-B	5	4.93	4.87	1.15	1	0.983	1.01	-2.76
5-H-5-C	5	4.97	4.92	1.06	1	0.991	1.00	-0.92
5-H-5-D	5	4.98	5.09	-2.23	1	0.993	1.01	-1.73
6-L-1-A	6.5	6.49	6.26	3.48	0.1	0.0989	0.0994	-0.52
6-L-1-B	6.5	6.43	6.22	3.28	0.1	0.0980	0.0983	-0.31
6-L-1-C	6.5	6.48	6.22	4.06	0.1	0.0988	0.0985	0.29
6-L-1-D	6.5	6.50	6.26	3.58	0.1	0.0990	0.102	-3.05
6-L-1-E	6.5	6.50	6.61	-1.75	0.1	0.0990	0.102	-3.05
6-L-3-A	6.5	6.40	6.26	2.18	0.1	0.0987	0.100	-1.36
6-L-3-B	6.5	6.35	6.22	1.98	0.1	0.0978	0.100	-2.28
6-L-3-C	6.5	6.40	6.18	3.44	0.1	0.0986	0.0987	-0.14
6-L-3-D	6.5	6.41	6.52	-1.79	0.1	0.0988	0.101	-2.27
6-L-3-E	6.5	6.41	6.61	-3.15	0.1	0.0988	0.100	-1.25
6-L-5-A	6.5	6.39	6.52	-2.17	0.1	0.0980	0.0984	-0.38
6-L-5-B	6.5	6.33	6.44	-1.72	0.1	0.0971	0.0974	-0.26
6-L-5-C	6.5	6.38	6.48	-1.59	0.1	0.0979	0.0987	-0.78
6-L-5-D	6.5	6.39	6.44	-0.70	0.1	0.0981	0.0984	-0.28

Table 2.3. (contd)

	Na Concentration (M)				OH Concentration (M)			
Simulant ID	Target	As Prepared	Analyzed	RPD (%)	Target	As Prepared	Analyzed	RPD (%)
6-L-5-E	6.5	6.39	7.05	-10.2	0.1	0.0981	0.0988	-0.68
6-L-6-A	6.5	6.41	6.61	-3.16	0.1	0.0985	0.0980	0.46
6-L-6-B	6.5	6.35	6.48	-2.04	0.1	0.0976	0.101	-3.52
6-L-6-C	6.5	6.40	6.48	-1.22	0.1	0.0984	0.0989	-0.55
6-L-6-D	6.5	6.42	6.57	-2.38	0.1	0.0986	0.0981	0.46
6-L-6-E	6.5	6.42	6.57	-2.38	0.1	0.0986	0.0980	0.56
6-H-1-A	6.5	6.42	6.31	1.71	1	0.984	0.995	-1.11
6-H-1-B	6.5	6.36	6.35	0.13	1	0.975	0.990	-1.51
6-H-1-C	6.5	6.41	6.31	1.61	1	0.983	0.990	-0.70
6-H-1-D	6.5	6.42	6.39	0.45	1	0.985	0.995	-1.01
6-H-1-E	6.5	6.42	6.22	3.16	1	0.985	0.995	-1.01
6-H-3-A	6.5	6.47	6.35	1.81	1	0.993	1.01	-1.75
6-H-3-B	6.5	6.41	6.26	2.28	1	0.984	1.01	-2.68
6-H-3-C	6.5	6.46	6.35	1.72	1	0.992	1.00	-0.85
6-H-3-D	6.5	6.47	6.35	1.91	1	0.994	1.02	-2.66
6-H-3-E	6.5	6.47	6.05	6.62	1	0.994	0.995	-0.14
6-H-5-A	6.5	6.45	6.22	3.59	1	0.990	1.01	-2.06
6-H-5-B	6.5	6.39	6.18	3.39	1	0.981	0.995	-1.46
6-H-5-C	6.5	6.45	6.31	2.14	1	0.989	0.995	-0.65
6-H-5-D	6.5	6.46	6.22	3.68	1	0.991	1.02	-2.97
6-H-5-E	6.5	6.46	6.39	0.99	1	0.991	1.03	-3.98
6-H-6-A	6.5	6.44	6.18	4.14	1	0.986	1.01	-2.39
6-H-6-B	6.5	6.39	6.05	5.31	1	0.978	0.995	-1.78
6-H-6-C	6.5	6.44	6.13	4.72	1	0.985	0.995	-0.97
6-H-6-D	6.5	6.45	6.22	3.56	1	0.987	0.995	-0.77
6-H-6-E	6.5	6.45	6.18	4.23	1	0.987	1.01	-2.28
8-L-1-A	8	7.99	7.87	1.46	0.1	0.0995	0.0978	1.75
8-L-1-B	8	7.91	7.74	2.17	0.1	0.0986	0.0971	1.57
8-L-1-C	8	7.98	7.87	1.32	0.1	0.0994	0.0971	2.35
8-L-1-D	8	7.99	7.92	0.97	0.1	0.0996	0.0978	1.85
8-L-1-E	8	7.99	7.83	2.06	0.1	0.0996	0.0967	2.95
8-L-3-A	8	7.99	7.83	2.04	0.1	0.0997	0.0980	1.74
8-L-3-B	8	7.92	7.70	2.79	0.1	0.0988	0.0947	4.18
8-L-3-C	8	7.98	7.96	0.31	0.1	0.0996	0.0955	4.15
8-L-3-D	8	8.00	7.74	3.22	0.1	0.0998	0.100	-0.17
8-L-3-E	8	8.00	7.74	3.22	0.1	0.0998	0.0955	4.34
8-L-5-A	8	8.00	7.44	6.98	0.1	0.0998	0.0969	2.87
8-L-5-B	8	7.91	7.83	1.00	0.1	0.0987	0.0953	3.41
8-L-5-C	8	7.99	7.74	3.08	0.1	0.0997	0.0958	3.87
8-L-5-D	8	8.00	7.96	0.55	0.1	0.0999	0.0990	0.86
8-L-5-E	8	8.00	7.92	1.10	0.1	0.0999	0.0962	3.67
8-L-6-A	8	7.99	7.53	5.85	0.1	0.0997	0.0965	3.18
8-L-6-B	8	7.92	7.83	1.15	0.1	0.0988	0.0964	2.40
8-L-6-C	8	7.98	8.00	-0.24	0.1	0.0996	0.0953	4.28
8-L-6-D	8	8.00	8.00	-0.04	0.1	0.0998	0.0983	1.47
8-L-6-E	8	8.00	7.96	0.50	0.1	0.0998	0.0964	3.37
8-H-1-A	8	8.00	7.87	1.54	1	0.997	1.02	-2.29

Table 2.3. (contd)

Simulant ID	Na Concentration (M) Target	As Prepared	Analyzed	RPD (%)	OH Concentration (M) Target	As Prepared	Analyzed	RPD (%)
8-H-1-B	8	7.92	7.92	0.09	1	0.988	0.965	2.35
8-H-1-C	8	7.99	8.00	-0.20	1	0.996	0.970	2.63
8-H-1-D	8	8.00	8.00	0.00	1	0.998	0.950	4.82
8-H-1-E	8	8.00	7.96	0.55	1	0.998	0.965	3.32
8-H-3-A	8	7.99	8.18	-2.32	1	0.997	1.02	-2.28
8-H-3-B	8	7.92	7.92	0.04	1	0.988	1.00	-1.19
8-H-3-C	8	7.98	8.09	-1.34	1	0.996	1.01	-1.38
8-H-3-D	8	8.00	7.83	2.13	1	0.998	1.01	-1.18
8-H-3-E	8	8.00	8.00	-0.05	1	0.998	1.01	-1.18
8-H-5-A	8	8.00	8.00	-0.07	1	0.997	1.02	-2.30
8-H-5-B	8	7.93	8.00	-0.98	1	0.988	1.02	-3.23
8-H-5-C	8	7.99	7.96	0.38	1	0.996	1.03	-3.41
8-H-5-D	8	8.01	7.92	1.12	1	0.998	1.01	-1.19
8-H-5-E	8	8.01	7.92	1.12	1	0.998	1.00	-0.19
8-H-6-A	8	7.99	7.87	1.50	1	0.997	1.00	-0.29
8-H-6-B	8	7.92	7.83	1.16	1	0.988	1.00	-1.20
8-H-6-C	8	7.99	7.87	1.41	1	0.996	1.00	-0.39
8-H-6-D	8	8.00	7.96	0.51	1	0.998	1.00	-0.19
8-H-6-E	8	8.00	7.87	1.60	1	0.998	1.00	-0.19

Table 2.4. Batch Contact Feed Simulants – K and Cs Contents

Simulant ID	K Concentration (M) Target	As Prepared	Analyzed	RPD (%)	Cs Concentration (M) Target	As Prepared	Analyzed	RPD (%)
5-H-2-A	0.005	4.93E-03	6.01E-03	-21.88	5.00E-06	5.01E-06	5.06E-06	-1.00
5-H-2-B	0.005	4.89E-03	5.63E-03	-15.21	5.00E-05	5.04E-05	4.86E-05	3.52
5-H-2-C	0.005	4.93E-03	5.65E-03	-14.69	5.00E-04	4.99E-04	4.88E-04	2.22
5-H-2-D	0.005	4.94E-03	5.83E-03	-18.11	5.00E-03	5.01E-03	4.96E-03	1.05
5-H-4-A	0.05	4.98E-02	4.81E-02	3.36	5.00E-06	4.97E-06	4.94E-06	0.59
5-H-4-B	0.05	4.93E-02	4.78E-02	3.00	5.00E-05	5.08E-05	4.89E-05	3.80
5-H-4-C	0.05	4.97E-02	4.76E-02	4.29	5.00E-04	4.98E-04	4.70E-04	5.65
5-H-4-D	0.05	4.98E-02	4.83E-02	2.95	5.00E-03	4.99E-03	4.86E-03	2.55
5-H-5-A	0.35	3.48E-01	3.40E-01	2.19	5.00E-06	5.02E-06	4.97E-06	1.09
5-H-5-B	0.35	3.45E-01	3.35E-01	2.78	5.00E-05	5.12E-05	4.91E-05	4.16
5-H-5-C	0.35	3.47E-01	3.40E-01	2.09	5.00E-04	4.98E-04	4.86E-04	2.34
5-H-5-D	0.35	3.48E-01	3.53E-01	-1.39	5.00E-03	5.02E-03	4.95E-03	1.45
6-L-1-A	0	0.00E+00	3.09E-04	NA	5.00E-06	5.03E-06	5.17E-06	-2.87
6-L-1-B	0	0.00E+00	3.17E-04	NA	5.00E-05	5.07E-05	4.94E-05	2.57
6-L-1-C	0	0.00E+00	2.92E-04	NA	5.00E-04	5.05E-04	4.93E-04	2.40
6-L-1-D	0	0.00E+00	3.04E-04	NA	5.00E-03	5.02E-03	4.84E-03	3.50
6-L-1-E	0	0.00E+00	3.09E-04	NA	5.00E-02	4.99E-02	4.73E-02	5.26
6-L-3-A	0.035	3.45E-02	3.27E-02	5.16	5.00E-06	4.94E-06	6.94E-06	-40.37
6-L-3-B	0.035	3.42E-02	3.25E-02	5.04	5.00E-05	5.08E-05	4.85E-05	4.51
6-L-3-C	0.035	3.45E-02	3.27E-02	5.06	5.00E-04	4.96E-04	4.73E-04	4.58
6-L-3-D	0.035	3.46E-02	3.50E-02	-1.41	5.00E-03	5.02E-03	5.08E-03	-1.14
6-L-3-E	0.035	3.46E-02	3.53E-02	-2.15	5.00E-02	5.01E-02	5.01E-02	-0.07

Table 2.4. (contd)

	K Concentration (M)				Cs Concentration (M)			
Simulant ID	Target	As Prepared	Analyzed	RPD (%)	Target	As Prepared	Analyzed	RPD (%)
6-L-5-A	0.35	3.43E-01	3.48E-01	-1.39	5.00E-06	4.96E-06	4.91E-06	1.09
6-L-5-B	0.35	3.40E-01	3.43E-01	-0.80	5.00E-05	5.08E-05	5.14E-05	-1.13
6-L-5-C	0.35	3.43E-01	3.50E-01	-2.23	5.00E-04	4.98E-04	4.88E-04	2.03
6-L-5-D	0.35	3.43E-01	3.45E-01	-0.54	5.00E-03	5.01E-03	4.98E-03	0.65
6-L-5-E	0.35	3.43E-01	3.79E-01	-10.22	5.00E-02	5.01E-02	4.98E-02	0.65
6-L-6-A	0.5	4.93E-01	5.12E-01	-3.71	5.00E-06	4.99E-06	4.73E-06	5.20
6-L-6-B	0.5	4.89E-01	5.01E-01	-2.56	5.00E-05	5.09E-05	4.79E-05	5.85
6-L-6-C	0.5	4.93E-01	4.99E-01	-1.22	5.00E-04	4.99E-04	4.86E-04	2.67
6-L-6-D	0.5	4.94E-01	5.12E-01	-3.61	5.00E-03	4.99E-03	4.81E-03	3.55
6-L-6-E	0.5	4.94E-01	4.99E-01	-1.02	5.00E-02	4.99E-02	4.87E-02	2.48
6-H-1-A	0	0.00E+00	5.83E-04	NA	5.00E-06	4.97E-06	4.94E-06	0.69
6-H-1-B	0	0.00E+00	5.81E-04	NA	5.00E-05	5.08E-05	4.91E-05	3.40
6-H-1-C	0	0.00E+00	6.22E-04	NA	5.00E-04	4.98E-04	4.89E-04	1.78
6-H-1-D	0	0.00E+00	5.83E-04	NA	5.00E-03	4.98E-03	4.98E-03	-0.07
6-H-1-E	0	0.00E+00	5.86E-04	NA	5.00E-02	5.02E-02	4.85E-02	3.37
6-H-3-A	0.035	3.49E-02	3.48E-02	0.38	5.00E-06	5.07E-06	5.27E-06	-3.98
6-H-3-B	0.035	3.46E-02	3.35E-02	3.17	5.00E-05	5.08E-05	4.79E-05	5.69
6-H-3-C	0.035	3.49E-02	3.45E-02	1.01	5.00E-04	5.02E-04	4.85E-04	3.35
6-H-3-D	0.035	3.50E-02	3.43E-02	1.94	5.00E-03	4.99E-03	4.81E-03	3.55
6-H-3-E	0.035	3.50E-02	3.25E-02	7.06	5.00E-02	5.02E-02	4.74E-02	5.66
6-H-5-A	0.35	3.47E-01	3.30E-01	4.97	5.00E-06	5.00E-06	4.73E-06	5.39
6-H-5-B	0.35	3.44E-01	3.25E-01	5.60	5.00E-05	5.10E-05	4.93E-05	3.29
6-H-5-C	0.35	3.47E-01	3.38E-01	2.67	5.00E-04	4.97E-04	4.82E-04	3.10
6-H-5-D	0.35	3.48E-01	3.30E-01	5.07	5.00E-03	5.02E-03	4.85E-03	3.34
6-H-5-E	0.35	3.48E-01	3.40E-01	2.12	5.00E-02	5.00E-02	4.76E-02	4.88
6-H-6-A	0.5	4.96E-01	4.76E-01	4.16	5.00E-06	4.99E-06	4.79E-06	4.10
6-H-6-B	0.5	4.92E-01	4.63E-01	5.89	5.00E-05	5.08E-05	4.79E-05	5.73
6-H-6-C	0.5	4.96E-01	4.65E-01	6.12	5.00E-04	4.95E-04	4.69E-04	5.20
6-H-6-D	0.5	4.97E-01	4.76E-01	4.25	5.00E-03	4.98E-03	4.81E-03	3.35
6-H-6-E	0.5	4.97E-01	4.76E-01	4.25	5.00E-02	4.98E-02	4.70E-02	5.59
8-L-1-A	0	0.00E+00	3.27E-04	NA	5.00E-06	4.99E-06	4.96E-06	0.59
8-L-1-B	0	0.00E+00	3.02E-04	NA	5.00E-05	5.09E-05	4.88E-05	4.20
8-L-1-C	0	0.00E+00	3.35E-04	NA	5.00E-04	4.99E-04	4.90E-04	1.73
8-L-1-D	0	0.00E+00	3.27E-04	NA	5.00E-03	4.98E-03	4.35E-03	12.59
8-L-1-E	0	0.00E+00	3.09E-04	NA	5.00E-02	4.98E-02	4.78E-02	4.07
8-L-3-A	0.035	3.50E-02	3.38E-02	3.53	5.00E-06	5.00E-06	5.32E-06	-6.41
8-L-3-B	0.035	3.47E-02	3.38E-02	2.65	5.00E-05	5.10E-05	4.99E-05	2.14
8-L-3-C	0.035	3.50E-02	3.45E-02	1.24	5.00E-04	4.96E-04	4.88E-04	1.65
8-L-3-D	0.035	3.50E-02	3.40E-02	2.90	5.00E-03	4.99E-03	5.00E-03	-0.16
8-L-3-E	0.035	3.50E-02	3.32E-02	5.09	5.00E-02	4.98E-02	4.89E-02	1.81
8-L-5-A	0.35	3.49E-01	3.25E-01	7.01	5.00E-06	5.06E-06	5.06E-06	-0.08
8-L-5-B	0.35	3.45E-01	3.45E-01	0.05	5.00E-05	6.24E-05	4.49E-05	28.10
8-L-5-C	0.35	3.49E-01	3.38E-01	3.25	5.00E-04	5.09E-04	4.83E-04	5.07
8-L-5-D	0.35	3.50E-01	3.48E-01	0.52	5.00E-03	5.00E-03	5.06E-03	-1.13
8-L-5-E	0.35	3.50E-01	3.45E-01	1.25	5.00E-02	5.02E-02	4.91E-02	2.23
8-L-6-A	0.5	4.99E-01	4.73E-01	5.23	5.00E-06	4.95E-06	5.24E-06	-5.88
8-L-6-B	0.5	4.95E-01	4.81E-01	2.82	5.00E-05	5.02E-05	4.74E-05	5.58
8-L-6-C	0.5	4.99E-01	5.04E-01	-1.02	5.00E-04	5.00E-04	4.75E-04	4.92

Table 2.4. (contd)

	K Concentration (M)				Cs Concentration (M)			
Simulant ID	Target	As Prepared	Analyzed	RPD (%)	Target	As Prepared	Analyzed	RPD (%)
8-L-6-D	0.5	5.00E-01	4.96E-01	0.72	5.00E-03	4.99E-03	4.98E-03	0.14
8-L-6-E	0.5	5.00E-01	4.99E-01	0.21	5.00E-02	5.00E-02	4.82E-02	3.69
8-H-1-A	0	0.00E+00	5.91E-04	NA	5.00E-06	5.00E-06	5.18E-06	-3.50
8-H-1-B	0	0.00E+00	5.60E-04	NA	5.00E-05	5.04E-05	4.85E-05	3.68
8-H-1-C	0	0.00E+00	6.47E-04	NA	5.00E-04	4.99E-04	4.84E-04	3.02
8-H-1-D	0	0.00E+00	6.16E-04	NA	5.00E-03	5.01E-03	4.95E-03	1.25
8-H-1-E	0	0.00E+00	6.29E-04	NA	5.00E-02	5.02E-02	4.89E-02	2.60
8-H-3-A	0.035	3.49E-02	3.58E-02	-2.47	5.00E-06	5.03E-06	4.99E-06	0.89
8-H-3-B	0.035	3.46E-02	3.48E-02	-0.44	5.00E-05	5.03E-05	4.79E-05	4.83
8-H-3-C	0.035	3.49E-02	3.53E-02	-1.10	5.00E-04	4.99E-04	4.76E-04	4.58
8-H-3-D	0.035	3.50E-02	3.45E-02	1.29	5.00E-03	5.01E-03	5.13E-03	-2.34
8-H-3-E	0.035	3.50E-02	3.53E-02	-0.90	5.00E-02	5.02E-02	4.93E-02	1.84
8-H-5-A	0.35	3.49E-01	3.48E-01	0.45	5.00E-06	5.02E-06	7.10E-06	-41.44
8-H-5-B	0.35	3.46E-01	3.45E-01	0.28	5.00E-05	5.03E-05	5.04E-05	-0.13
8-H-5-C	0.35	3.49E-01	3.40E-01	2.55	5.00E-04	5.03E-04	4.84E-04	3.77
8-H-5-D	0.35	3.50E-01	3.43E-01	2.01	5.00E-03	5.02E-03	5.03E-03	-0.25
8-H-5-E	0.35	3.50E-01	3.43E-01	2.01	5.00E-02	5.01E-02	4.85E-02	3.11
8-H-6-A	0.5	4.99E-01	4.89E-01	2.19	5.00E-06	4.95E-06	4.73E-06	4.35
8-H-6-B	0.5	4.95E-01	4.91E-01	0.79	5.00E-05	5.00E-05	4.73E-05	5.45
8-H-6-C	0.5	4.99E-01	4.91E-01	1.58	5.00E-04	4.94E-04	4.85E-04	1.74
8-H-6-D	0.5	5.00E-01	4.96E-01	0.76	5.00E-03	5.00E-03	5.10E-03	-2.02
8-H-6-E	0.5	5.00E-01	4.91E-01	1.78	5.00E-02	5.00E-02	4.88E-02	2.44

2.4 Batch Contact Experiments

It is imperative to know the exact mass of resin added to the batch contact sample. To this end, the H-form resin is preferred. A batch of resin can be partially dried (typically to 50% water content) to allow for accurate weighing with constant water content. Working with resin in the Na-form is not recommended because aliquoting and weighing are conducted in air and oxygen appears to attack the Na-form resin more readily than H-form resin. This approach is consistent with the ion exchange batch contact test protocol.[3] Corrections to the Na-form mass basis may be applied if the mass conversion factor from H-form to Na-form (I_{Na} Factor) is determined for this resin lot.

An aliquot of pretreated wet H-form resin, large enough to process one group of ~56 samples, was dried to a free-flowing state in a vacuum oven at ambient temperature (~20 °C). An aliquot from each resin preparation batch was removed for a gross F-factor (water content) determination; the remainder of the partially dried resin was flushed with nitrogen for intermediate storage. The gross F-factor resin aliquot was dried overnight at 50 °C. The mass of resin aliquoted for use in testing was targeted based on the gross F-factor analysis.

Six groups of Cs batch contact tests were completed. Half of the samples for one process temperature were tested at one time to accommodate limitations in sample handling; therefore a total of 6 groups (two each at 25, 35, and 50 °C) were processed. For each group, the following steps were implemented:

(3) Walker, DD. 2004. *Hanford RPP-WTP Alt Resin Program –Protocol P2-RF: Ion Exchange Batch Contact Tests*. SRNL-RPP-2004-00055, Rev. 0 Savannah River National Laboratory, Aiken, South Carolina,

1. 25 mL aliquots of the feed simulants were placed into 30 mL Nalgene, polyethylene, narrow-mouth bottles,
2. the bottles with simulant were placed into an IKA KS 4000 orbital shaker table (IKA Works, Wilmington, North Carolina) and equilibrated to the target temperature (25, 35, or 50 °C),
3. an initial F-factor resin sample was collected from the free-flowing partially dried resin,
4. the required amount of resin aliquots (targeting 0.25 g dry, H-form mass basis) were added to the bottles containing temperature-equilibrated simulant,
5. the headspaces of the bottles were purged with nitrogen and capped,
6. the bottles were returned to the IKA KS 4000 orbital shaker table,
7. a closing F-factor resin sample was collected.

The F-factor was measured for each batch of samples by taking a sample of resin at the beginning of the batching and another one at the completion of the batching. These F-factor samples were placed in an open glass vial in a vacuum oven at 50 °C and dried to constant mass. The F-factor was then calculated by dividing the weight of the dry resin by the initial undried weight of the resin. The batch-to-batch F-factors ranged from 0.44 to 0.70; within the test batch the initial and final F-factors agreed within 1%. The mass of resin added to each simulant batch contact sample was multiplied by the average of the initial and final batch F-factors to determine the dry H-form resin mass contacted with simulant.

A picture of the IKA KS 4000 orbital shaker table is shown in Figure 2.4. The batch contact temperature was measured using a calibrated Type K thermocouple and Fluke 52II temperature readout (Fluke, Everett, Washington) to maintain temperature within ±2 °C. The samples were rotated at 140 rpm in a 2 cm radius to ensure that samples were mixed thoroughly for the entire 72-hour contact time (equilibrium conditions are expected to be attained after 48 hours [Nash et al. 2006]).

Approximately 0.25 g dry H-form resin was contacted with ~25 mL of feed simulant solution, resulting in a phase ratio of ~100:1 solution volume to dry H-form resin mass (the phase ratios ranged from 76 to 120 with an average of 96). The batch-contacted sample IDs are the same as the simulant IDs with the additional suffix denoting the contact temperature. Selected simulants were processed in duplicate (designated with “D” suffix in the sample name). A total of 336 batch contact samples were processed.

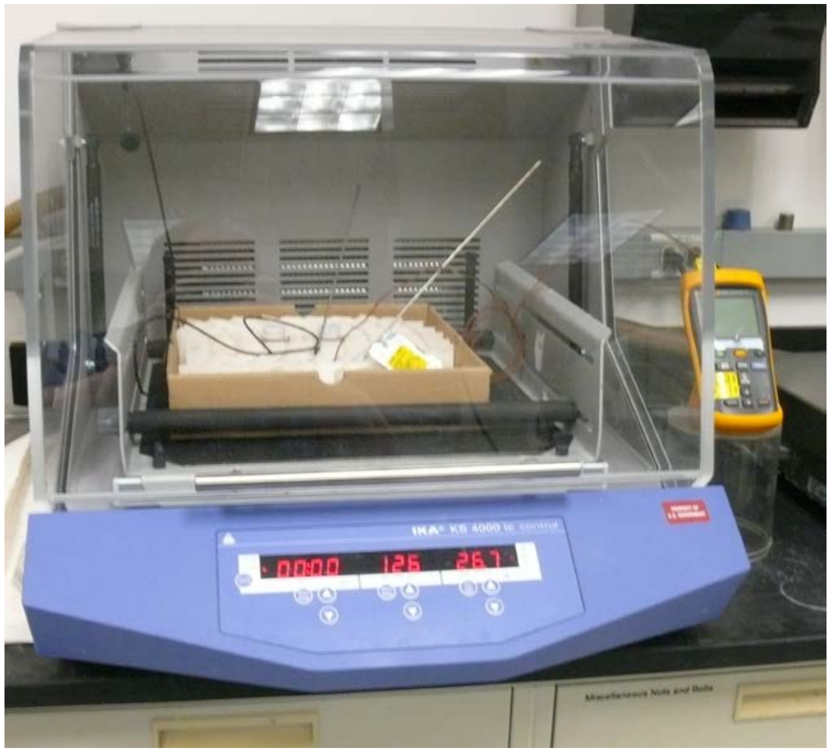


Figure 2.4. IKA KS 4000 Temperature-Controlled Orbital Shaker Table

Following the 72-hour contact time, the batch contact samples were phase separated. The resin was allowed to settle briefly, and then the aqueous phase was filtered using a syringe equipped with a 0.45-micron pore size opening nylon syringe filter. The aqueous phase was collected into a sample vial for delivery to SwRI and another vial for archive. Selected samples were analyzed in-house for density and water content.

Filtrate aliquots were submitted to SwRI under chain-of-custody control for analysis of Cs, Na, and K. A subset of ten selected samples was also analyzed for free OH^- by SwRI. Analysis of the post-batch-contacted samples at SwRI was conducted as previously described for the feed samples. The ten selected samples were also chosen for measurement of the post-batch-contact-test density and wt% water. The density was measured using the mass of solution placed in a 10 mL volumetric flask. The wt% dissolved solids was measured using a Mettler moisture analyzer according to PNNL technical procedure OP-WTPSP-004, Rev. 1.0, *Operation of the Mettler Moisture Analyzer*. The water content was calculated by difference (100% minus the wt% dissolved solids).

The Cs loaded onto the resin at equilibrium condition was calculated according to Equation 2.2.

$$Cs_R = \frac{(C_i - C_f) \times V}{M_R \times F} \tag{2.2}$$

where
- Cs_R = resin loading, mmol Cs/g dry H-form resin
- C_i = initial Cs concentration, M
- C_f = final Cs concentration, M
- V = volume of simulant, mL
- M_R = mass of H-form resin (as-measured), g
- F = F-factor, correction factor to account for the water entrained in the resin pores (dry H-form resin divided by the as-weighed H-form resin), dimensionless.

3.0 Isotherm Results and Discussion

The effect of the initial Na concentration (5, 6.5, and 8 M), initial K concentration (0.00, 0.035, 0.05, 0.35, and 0.50 M), and initial OH concentration (0.1 and 1 M) on the sRF resin's Cs loading at temperatures of 25, 35, and 50 °C was tested using batch contact tests. The results of this research are discussed in this section. All post-contacted batch equilibrium Na, K, Cs, and OH concentration results are provided in Appendix C for use in detailed isotherm modeling.

3.1 Isotherms-General

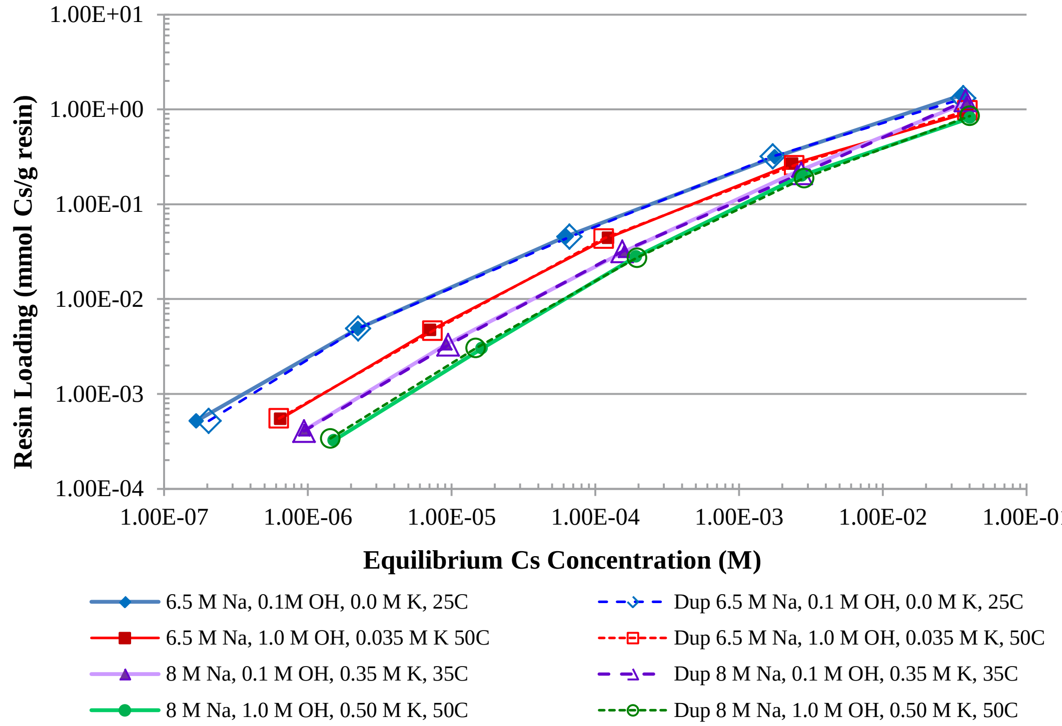
The isotherms plotted in this section show the equilibrium Cs loading (mmoles) on the sRF resin (dry H-form mass basis) as a function of the equilibrium Cs concentration (M) in the aqueous phase. In general, isotherms are presented on log-log plots to best show effects at low Cs concentrations. However, linear-linear plots are more useful for observing differences at high Cs concentrations. All data can be replotted using the input data provided in Appendix C and Appendix D.

The experimental precision was evaluated by conducting 12 batch contact isotherms in duplicate. Figure 3.1 shows 4 examples of the 12 replicate isotherms in both a log-log plot and linear-linear plot. In this example, the largest discrepancy is at the highest Cs concentration in the 6.5 M Na, 0.1 M OH, 0.0 M K tested at 25 °C isotherm where the sample and duplicate differ by 8% in the Cs loading capacity and 3% in the equilibrium Cs concentration. With one exception, all duplicate Cs load capacities for the sample and duplicate agreed within 10%; the majority agreed within 5%. The differences in these isotherms, attributed to overall experimental error, are very small. The Figure 3.1 isotherm set provides a visual guide for how much variation can be expected from one isotherm to the next simply from experimental error. This awareness of experimental uncertainty allows for a better understanding of the evaluation of matrix effects presented in the following sections.

3.1.1 Na Effect on Resin Cs Loading

Figure 3.2 presents the effect of different Na levels on resin Cs loading at 50 °C with K and OH concentrations of 0.35 and 1.0 M, respectively. These specific matrix conditions are presented in this graphical representation because they were tested herein at 5 M as well as 6.5 and 8 M Na and thus had the minimum amounts of the other variable conditions that could confound comparisons. Changes in Na concentration affects the Cs resin loading; as Na concentration increases, Cs loading decreases (see Figure 3.3). However, at the high Na concentrations of 6.5 and 8 M, the effect on the Cs loading is less pronounced than previously observed at lower (0.1 to 5 M) Na concentrations (Russell et al. 2014). Lower Na concentration appears to allow Cs to compete for the resin ion exchange sites more effectively as shown in Figure 3.3 (reproduced from Russell et al. [2014]) with current results added. The same effects were seen at 25 °C (Figure 3.4); however, at these Na levels the effect was even less pronounced with essentially no difference between the 6.5 and 8 M Na. Previous work (i.e., Nash et al. [2006] and Russell et al. [2014]) also observed this effect.

(a)



(b)

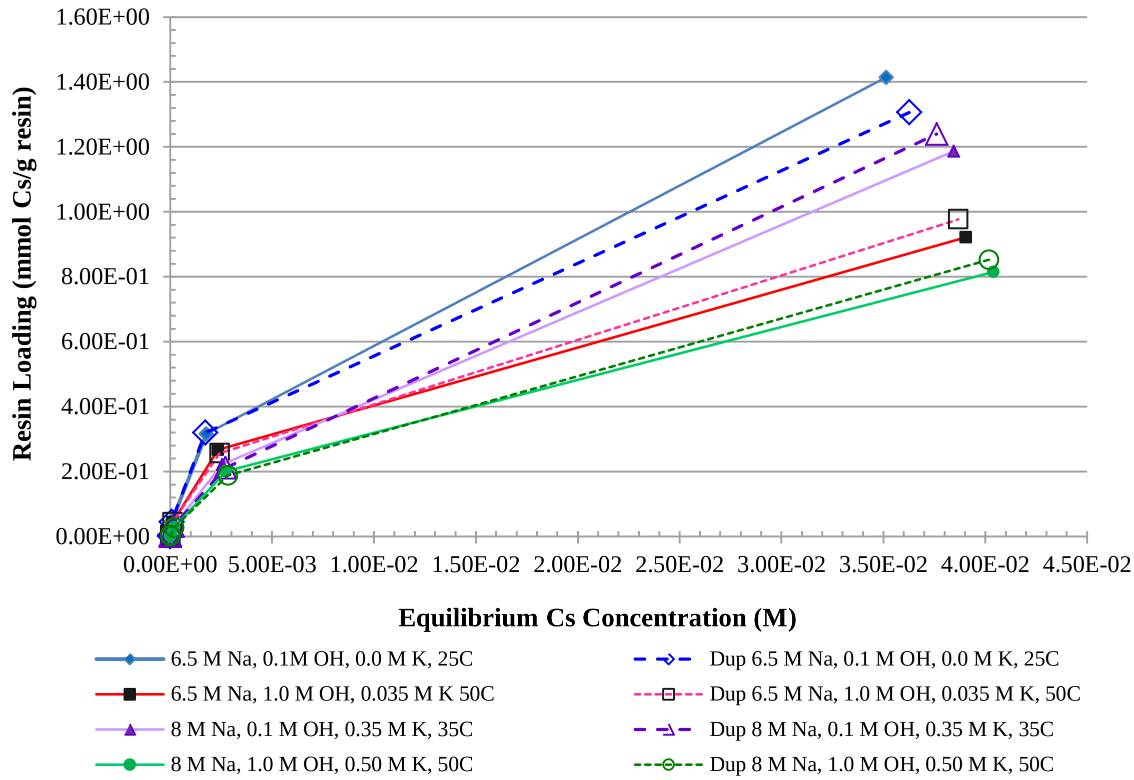


Figure 3.1. Replicate Isotherms for Precision Evaluation (a) Log-Log Plot (b) Linear-Linear Plot

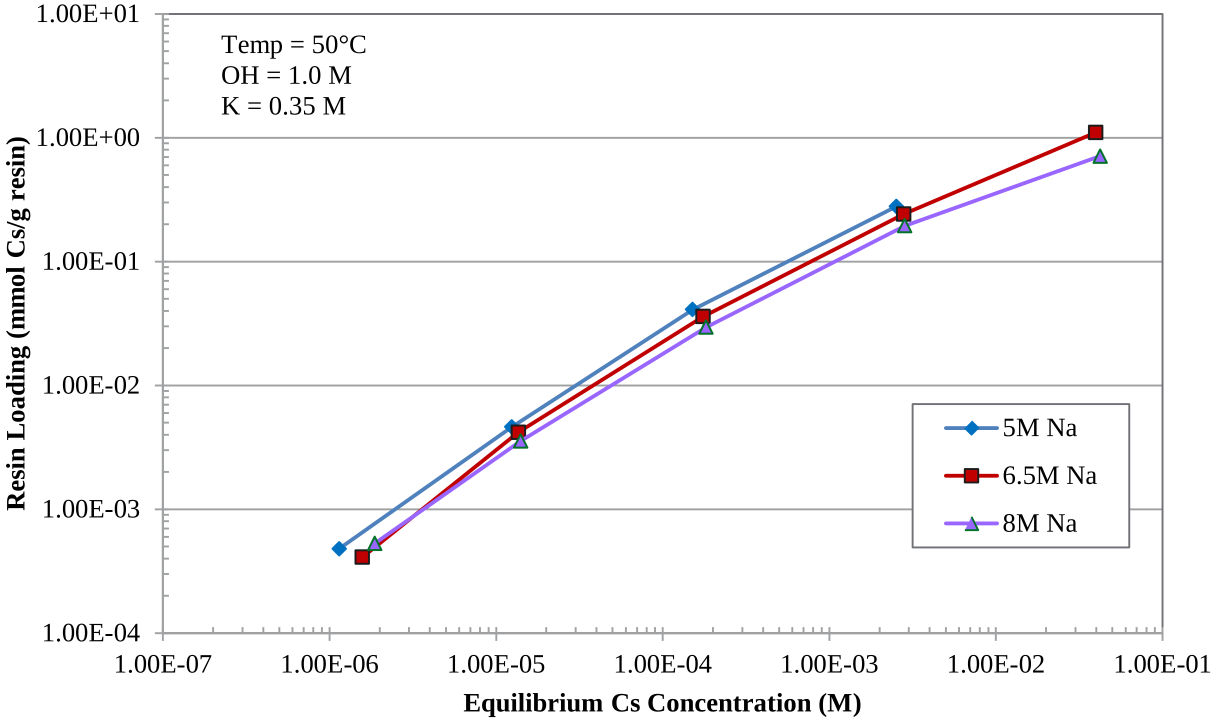


Figure 3.2. Na Effect on Cs Loading at 50 °C, 0.35 M K, and 1.0 M OH

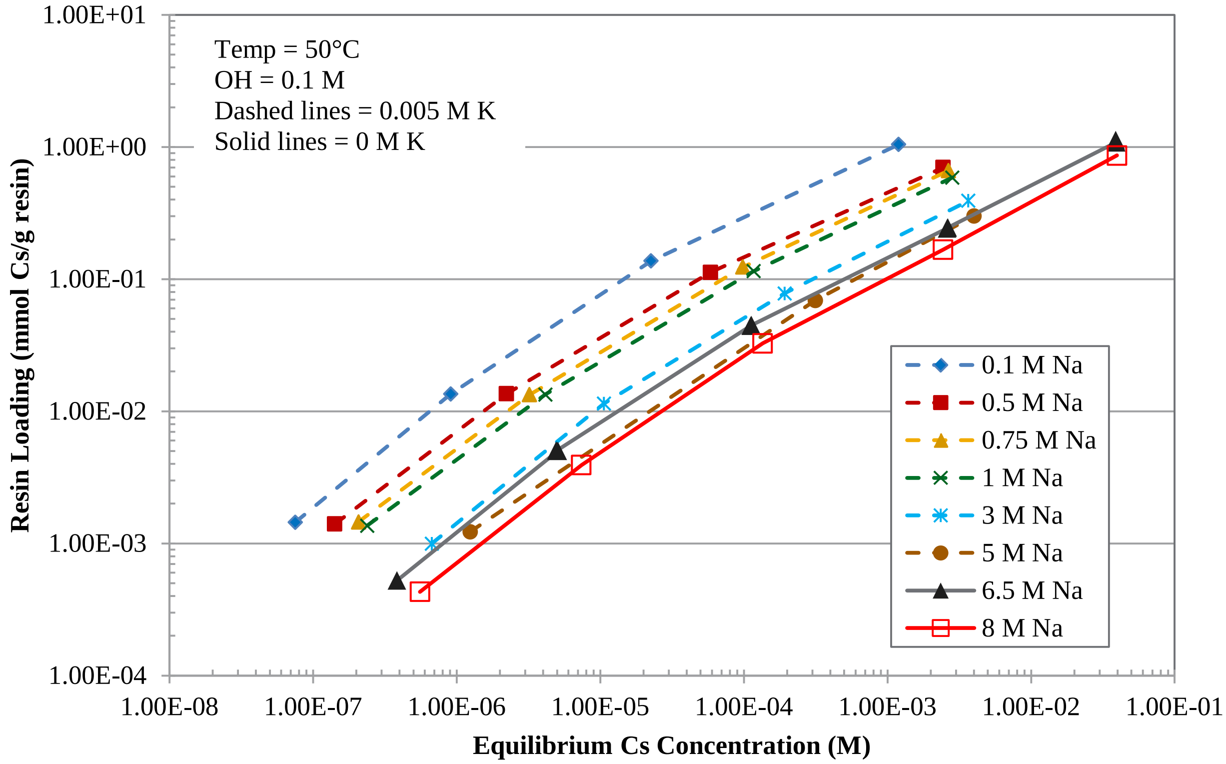


Figure 3.3. Na Effect on Cs Loading at 50 °C, 0.005 M K, and 0.1 M OH (Russell et al. [2014]) and 0 M K and 0.1 M OH (current testing)

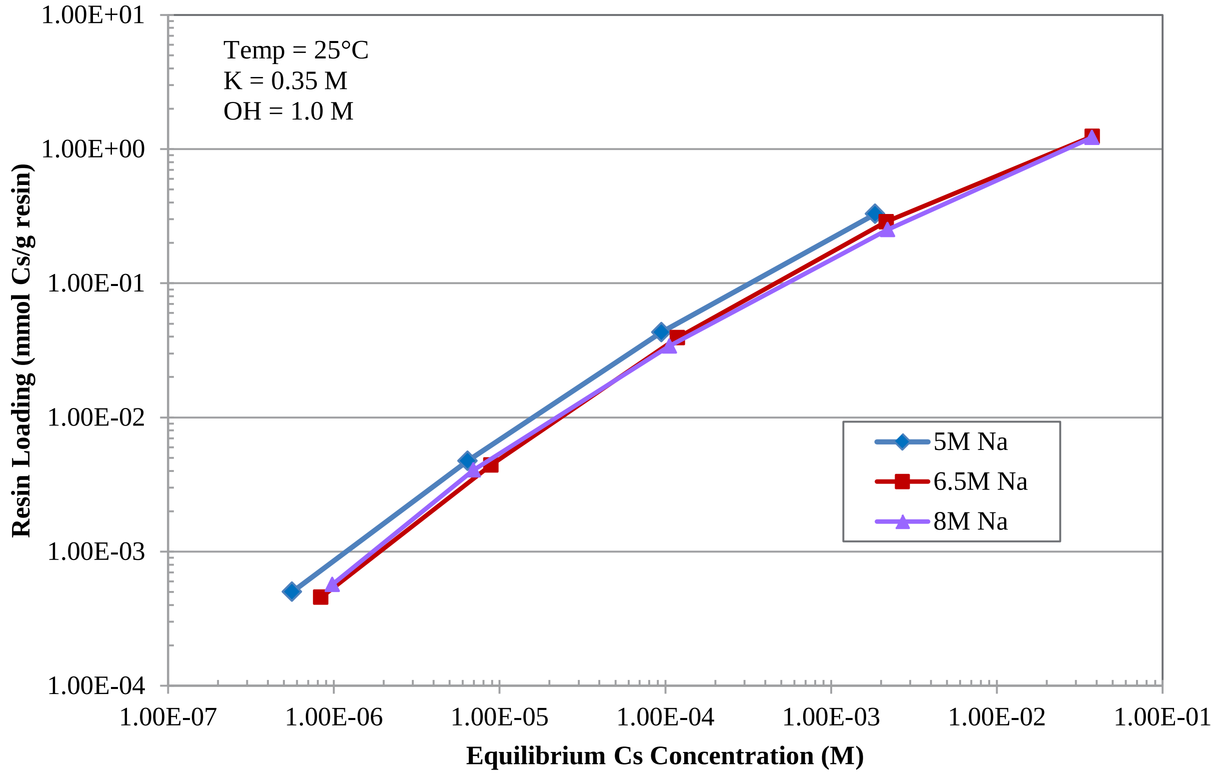


Figure 3.4. Na Effect on Cs Loading at 25 °C, 0.35 M K, and 1.0 M OH

3.1.2 K Effect on Resin Cs Loading

In this experimental design, it was not possible to deconvolute the effect of ionic strength change from a specific K effect on Cs exchange. Figure 3.5 presents the effect of different K levels on resin Cs loading at 50 °C with a 0.1 M OH concentration and 6.5 and 8 M Na concentrations. The effect of K on Cs loading appeared to vary. Lower Cs concentrations yielded greater K effect, which was expected due to competition for the resin sites between K and Cs. Higher Cs concentrations were less affected by K. At the two highest Cs concentrations tested (i.e., 0.005 and 0.05 M), no significant K effect was observed. This could be due to the fact that as more Cs is present, there is a greater competition for the resin sites between Cs and K. The affinity of the resin is higher for Cs than for K, causing it to load essentially the same amount of Cs with or without the K. Previous studies also noted this trend and observed that above a Cs concentration of 0.001 M, Cs adsorption was more favorable at higher K concentration (Nash and Isom 2010). Bray et al. (1996) reported similar results using ground gel resorcinol formaldehyde (RF) and neutralized current acid waste. At 0.003 M Cs with 3 M Na solution, K competition appeared to vanish. In addition, the effect of the K is slightly greater at 6.5 M Na than at 8 M Na, indicating again that at higher Na concentrations, Na takes the resin sites regardless of K concentration. The effect of K concentration on Cs resin loading at 25 °C with 0.1 M OH concentration and 6.5 and 8 M Na appears to be very similar at 50 °C (Figure 3.6).

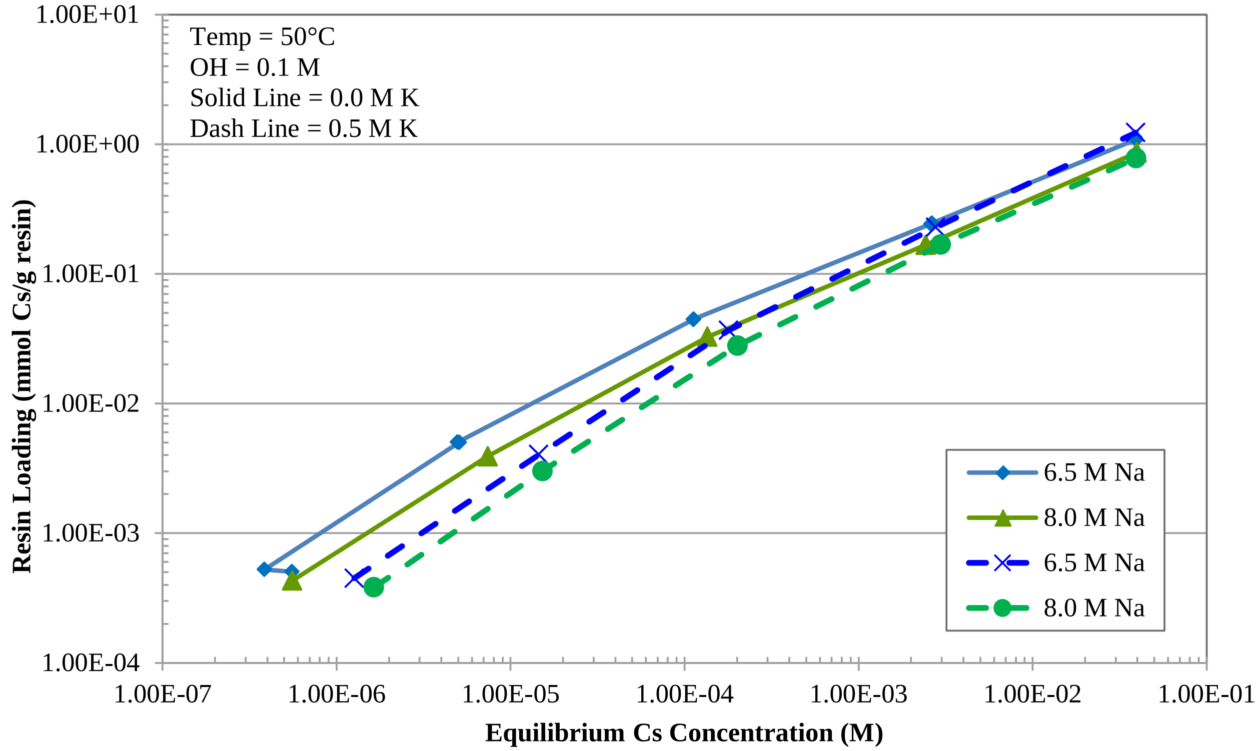


Figure 3.5. K Effect on Cs Loading at 50 °C, 6.5 and 8 M Na, and 0.1 M OH

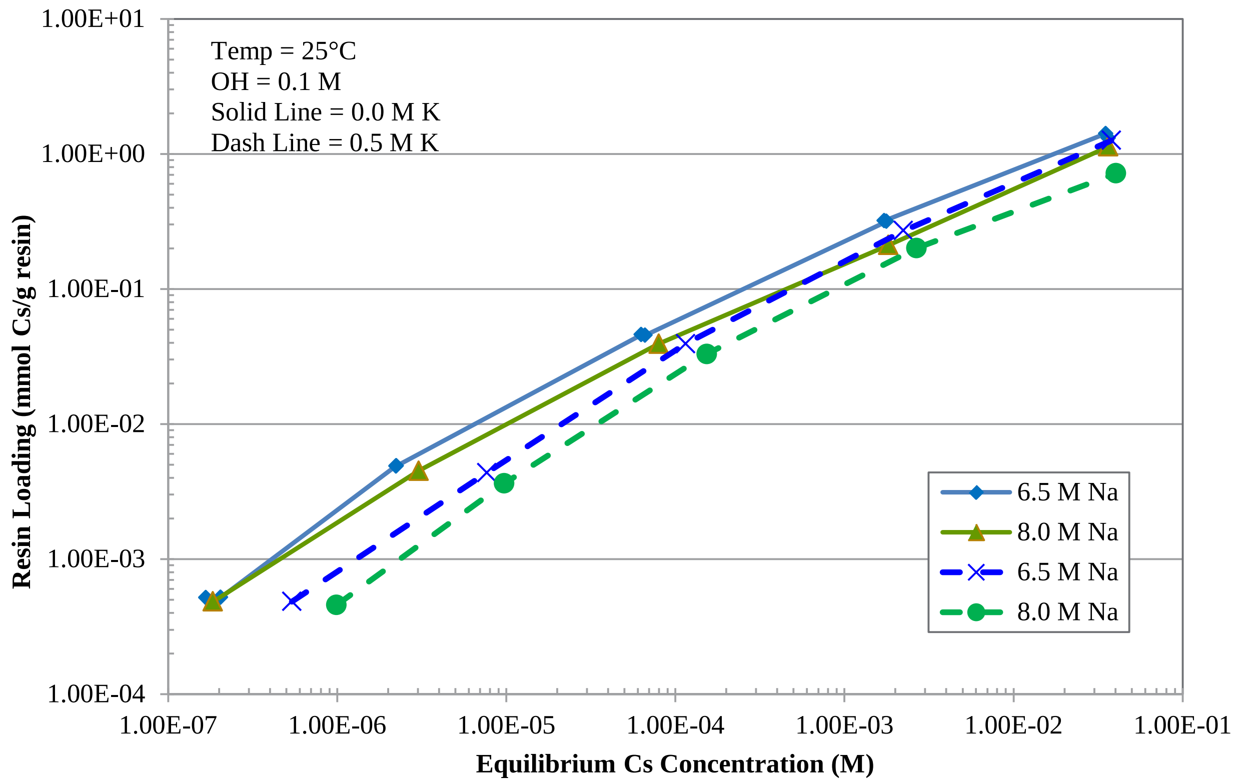


Figure 3.6. K Effect on Cs Loading at 25 °C, 6.5 and 8 M Na, and 0.1 M OH

3.1.3 OH Effect on Resin Cs Loading Capacity

Figure 3.7 and Figure 3.8 show that the effect of different OH levels on Cs loading is slightly larger at higher Na levels. A slightly larger difference was seen in Russell et al. (2014) at slightly lower Na concentrations. However, the feed used in this testing actually has an equilibrium concentration of 0.03 to 0.04 M OH (see Section 4.0) instead of 0.1 M OH, which made the difference tested even smaller and may have decreased the observed variance. OH concentration generally has a slightly positive effect at higher Cs concentrations. The presence of OH helps de-protonize the resin, opening up exchange sites and allowing the Cs ions to load more easily. Therefore, at higher Cs concentrations, more OH is needed to form the ionic sites on the resin to accept the Cs. If not enough OH is present to form these sites, Cs loading decreases. This effect was also observed in Nash et al. (2006) and Nash and Isom (2010). These results indicate that the presence of OH may help resin Cs loading at higher Cs concentrations, but probably will make a smaller difference in the presence of high Na and K concentrations where this effect is decreased.

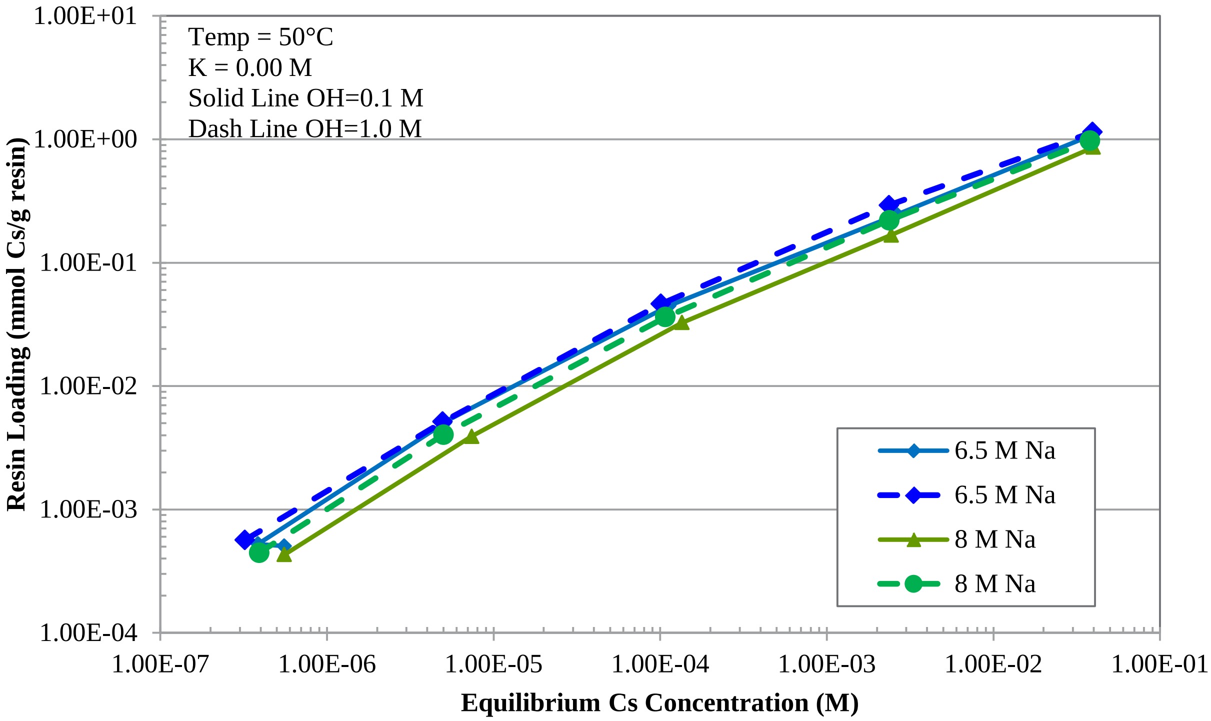


Figure 3.7. OH Effect on Cs Loading at 50°C and 0.00 M K

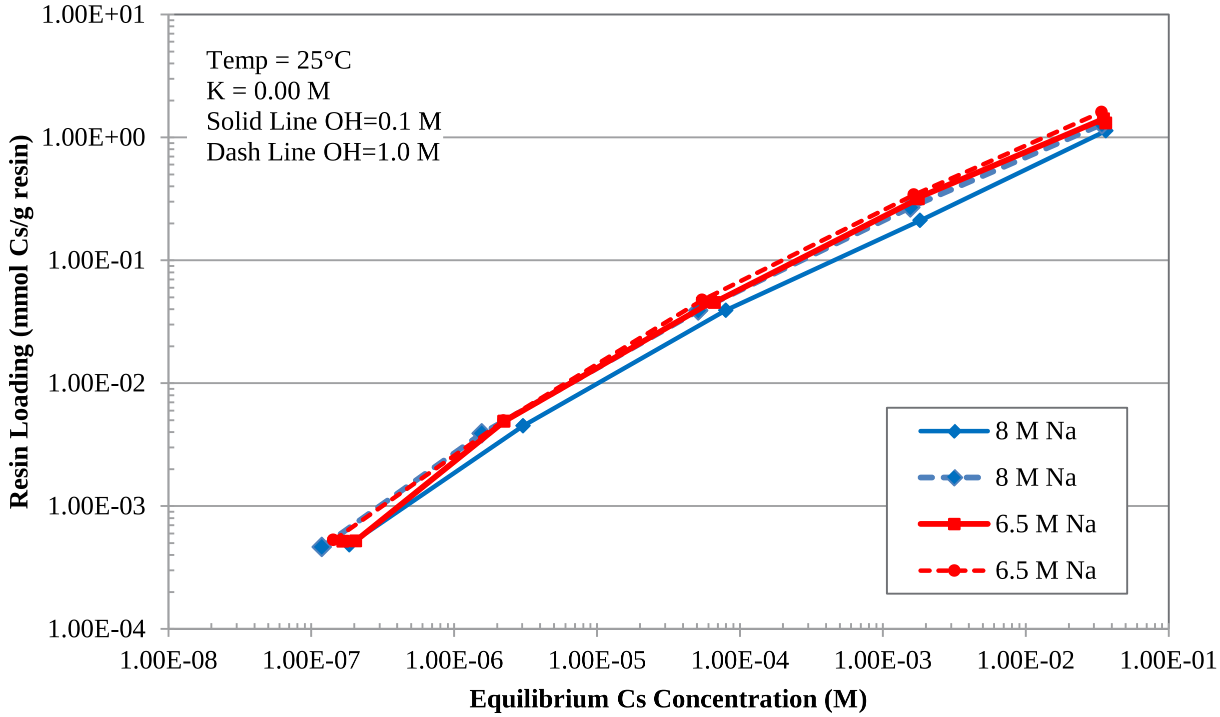


Figure 3.8. OH Effect on Cs Loading at 25°C and 0.00 M K

3.1.4 Temperature Effect on Resin Cs Loading Capacity

The effect of temperature on the resin Cs loading capacity appears to be dependent on Na concentration with decreasing Cs loading with increasing Na concentration. Figure 3.9 shows that the effect of temperature on Cs loading is higher at 8 M Na than at 6.5 M Na. In addition, the Cs loading of 6.5 M Na at 50 °C becomes essentially the same as 8 M Na at 25 °C at approximately 0.0005 M Cs and above.

The presence of K does appear to make a difference in the effect of temperature at low Cs concentration (Figure 3.10) with only a slight difference seen at higher Cs concentrations. At low Cs concentration, simulant without K at 50 °C loads more Cs than 0.50 M K at 25 °C. However, over the entire range tested, at a certain K concentration, the 25 °C loaded more Cs than the 50 °C with temperature having a larger effect at lower Cs concentrations. As K increases from 0 to 0.5 M, the decrease in Cs loading with increasing temperature narrows dramatically.

The temperature effect of OH appears to be dependent on the presence of Na (Figure 3.11 and Figure 3.12). At 6.5 M Na and 0.00 M K, Cs loading is similar at both OH concentrations; however, Cs loading decreases slightly when the temperature is raised to 50 °C. With 8 M Na and 0.00 M K, Cs loading was greater at 1.0 M OH than at 0.1 M OH; however, Cs loading decreased when the temperature was increased from 25 to 50 °C especially at lower Cs concentrations.

Overall, higher temperatures result in lower equilibrium Cs loadings. Increasing the temperature from 25 to 50 °C resulted in less Cs being removed from the simulant solution, with the percent decrease dependent on the presence of the other ions. This observation is in agreement with previous work (Nash et al. 2006) and implies that if a higher temperature is used in loading the sRF resin, it will obtain a lower equilibrium Cs loading level.

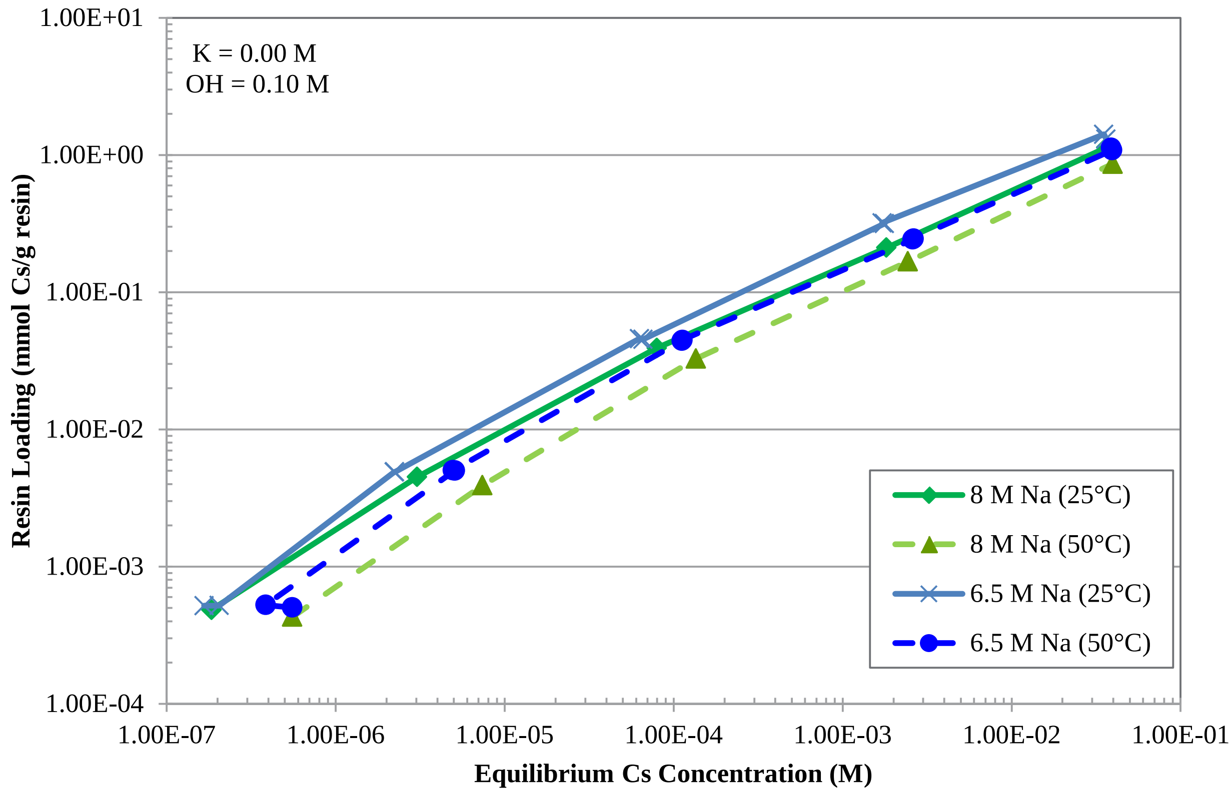


Figure 3.9. Temperature Effect of Na on Cs Loading at 0.1 M OH and 0.00 M K

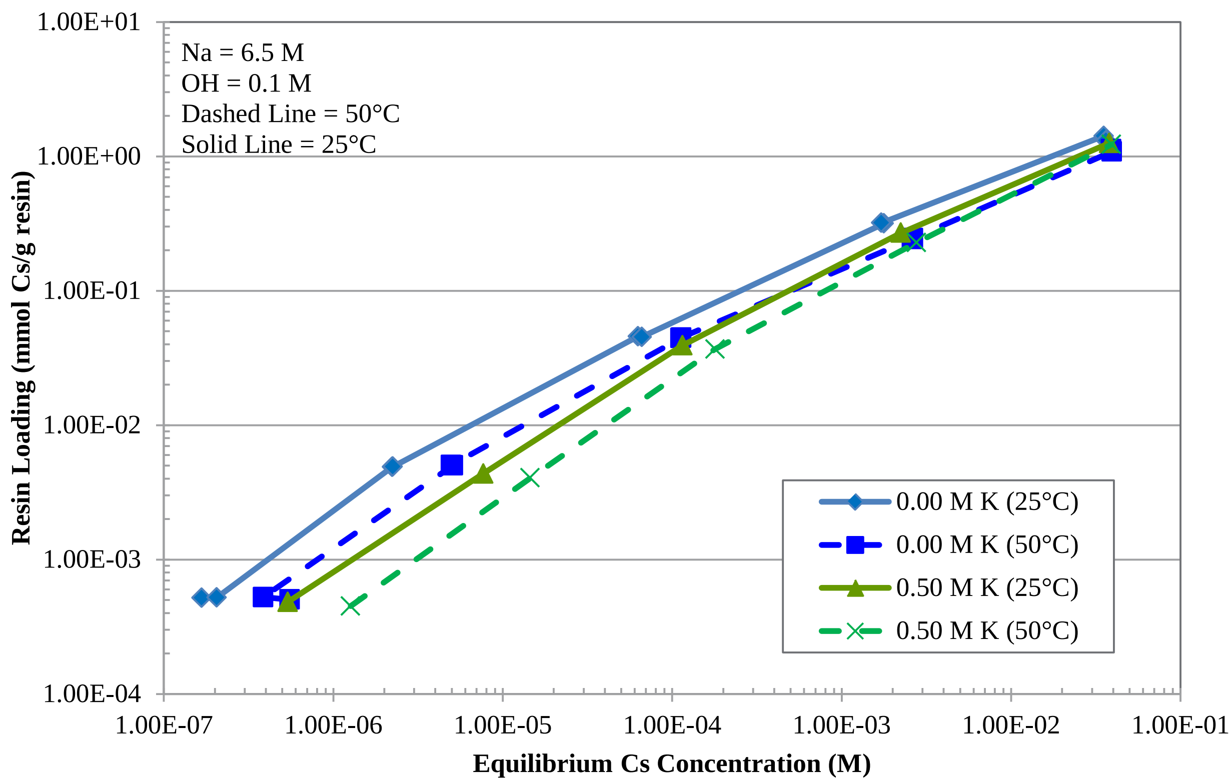


Figure 3.10. Temperature Effect of K on Cs Loading at 0.1 M OH and 6.5 M Na

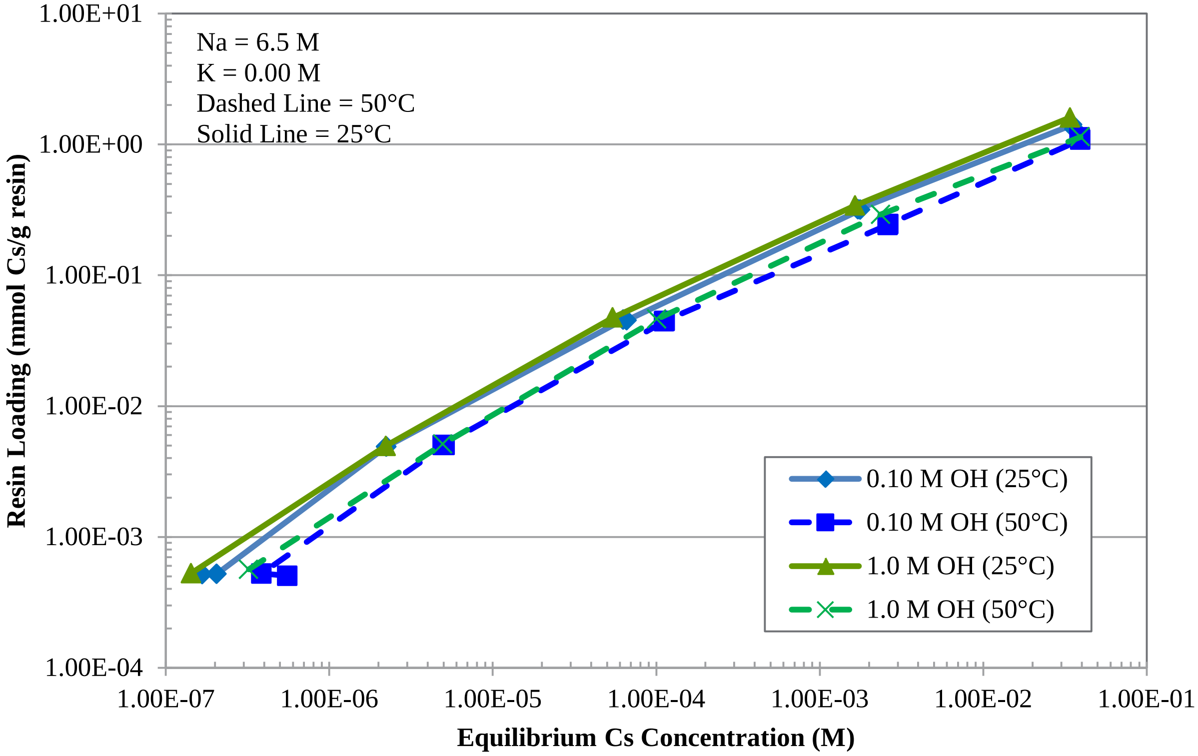


Figure 3.11. Temperature Effect of OH on Cs Loading at 6.5 M Na and 0.00 M K

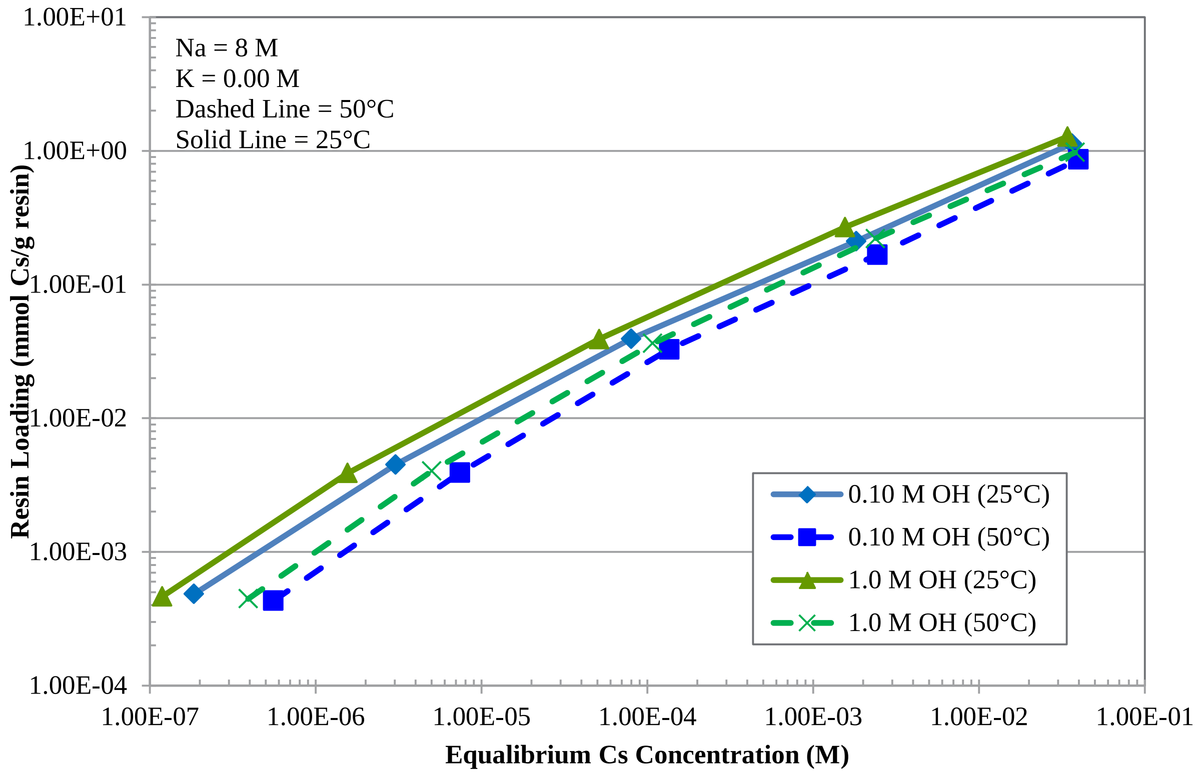


Figure 3.12. Temperature Effect of OH on Cs Loading at 8 M Na and 0.00 M K

3.2 A Comparison of FY12 (from Russell et al. 2014) and FY16 Testing

A comparison of the temperature effect was made between this testing and previous PNNL testing (Russell et al. 2014) at 5 M Na, 0.05 M K, and 1.0 M OH. As shown in Figure 3.13, the isotherm slopes were essentially the same, but the actual loading was slightly lower in the previous PNNL work. One reason for this may be that this current testing was performed under a nitrogen atmosphere and the previous PNNL work was performed under an air atmosphere. The presence of oxygen is known to degrade the resin, reducing its capacity.[1]

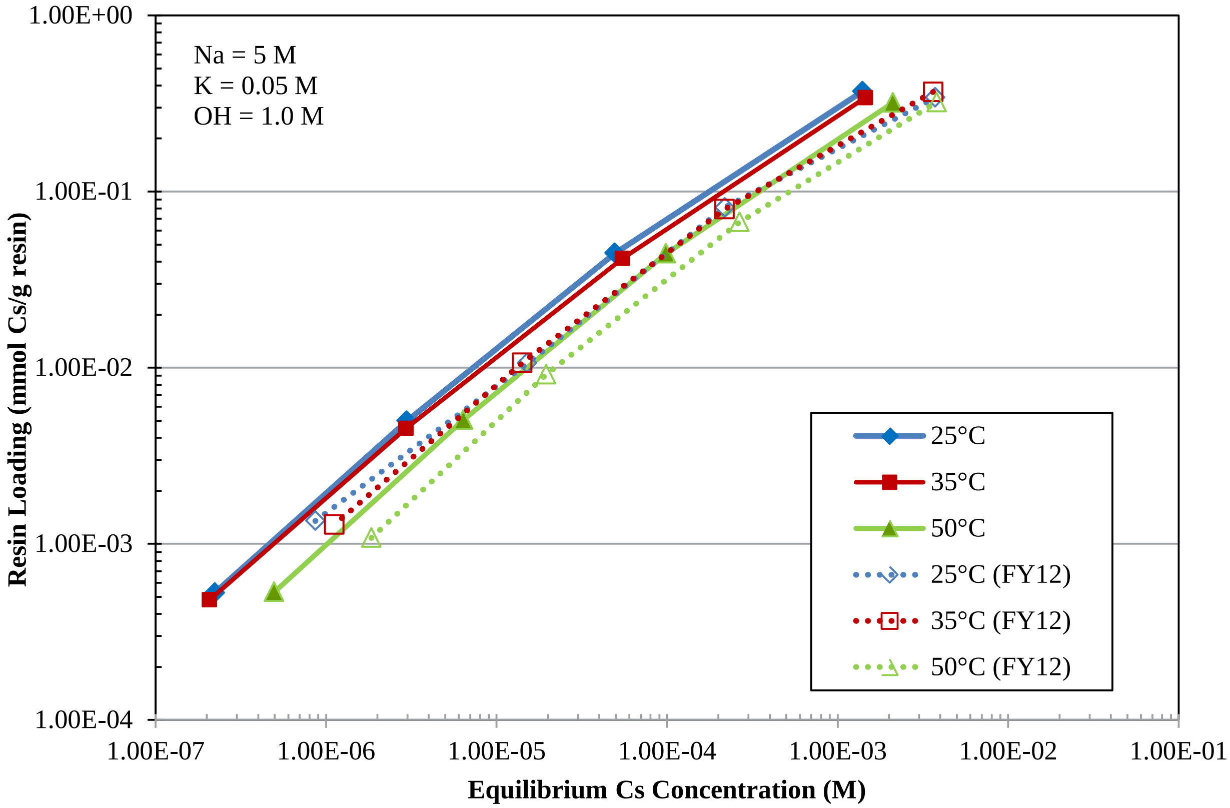


Figure 3.13. Temperature Effect on Cs Loading at 5 M Na, 1.0 M OH and 0.05 M K

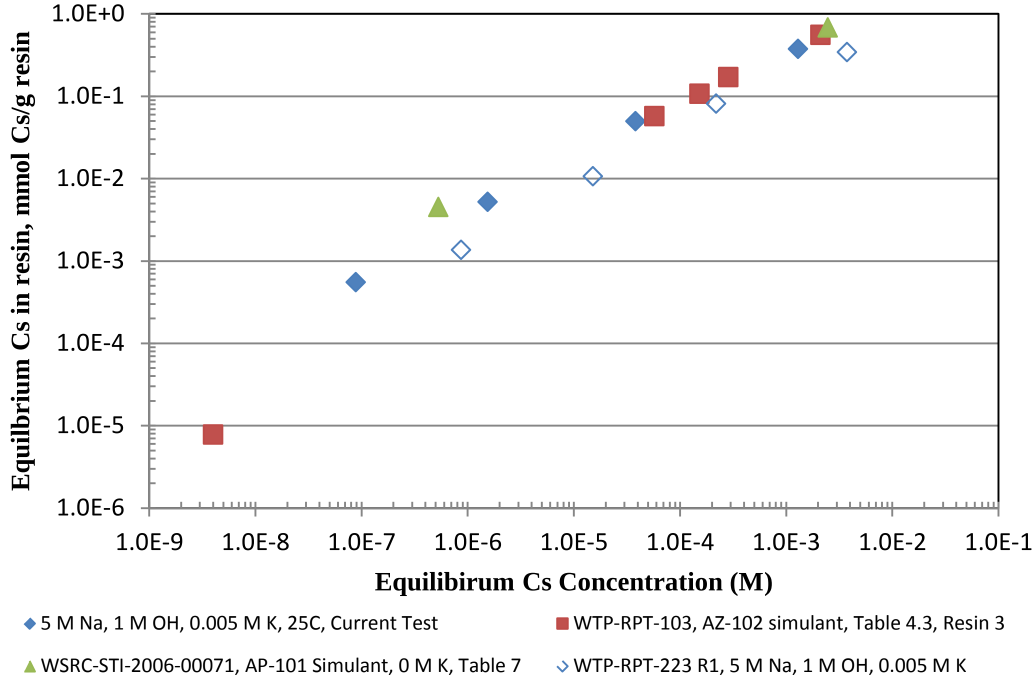
3.3 Isotherm Comparison with Previous Isotherms

A small subset of batch contacts was tested at 5 M Na and 1 M hydroxide and various K concentrations to compare directly with isotherm data presented in Russell et al. (2014). Results of these tests are provided in the following sections where applicable. Figure 3.14 compares current isotherm testing results using the 5 M Na, 1 M OH, and 0.005 M K matrix at 25 °C with the corresponding Russell et al. (2014) isotherm data. Isotherm comparison results are shown using two different axis formats (log-log and linear-linear). At low Cs concentrations, the current data set appears to be slightly higher in Cs loading than reported by Russell et al. (2014). Significant divergence is evident at high Cs concentration where the Russell et al. (2014) data shows a strong leveling off of Cs load capacity at about 0.34 mmol Cs per gram dry H-form resin. These observations are consistent with the use of an inert cover gas during the course of the batch contact period. The Russell et al. (2014) data set used ambient air as the cover gas

(1) Other experimental differences included a different sRF production lot, sRF storage conditions before testing, and higher phase ratio.

during the batch contact period. The oxygen in the air is known to adversely affect Cs loading. The effect of oxidative attack of finite Cs exchange sites is expected to be more pronounced at higher Cs concentrations.

(a)



(b)

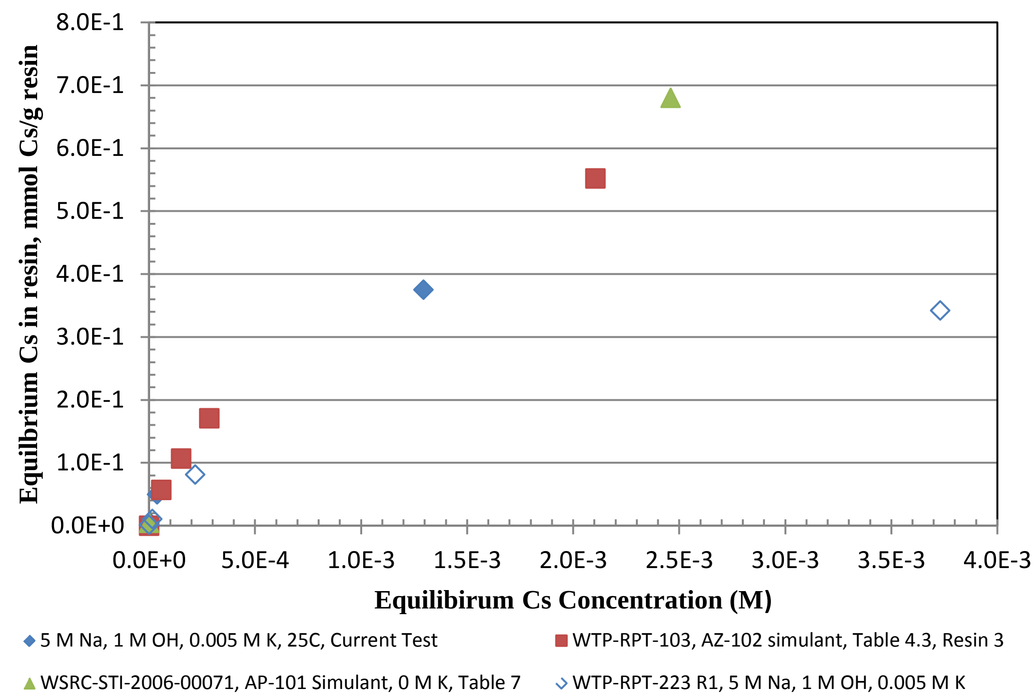


Figure 3.14. Isotherm Comparison of Current Testing to Previous Work (a) Log-Log Plot (b) Linear-Linear Plot

To better evaluate if the isotherm difference is strictly associated with the cover gas test condition, the current data set was also compared to other previously published data in Figure 3.14. Fiskum et al. (2004) tested sRF "Resin #3" (among others) with AZ-102 simulant composed of 5.2 M Na, 0.21 M OH, and 0.15 M K. Nash et al. (2006) tested sRF with a modified AP-101 simulant composed of 5 M Na, 1.9 M OH, and 0 M K. The current data set isotherm aligns well at high and low Cs concentrations with the Fiskum et al. (2004) and Nash et al. (2006) isotherms, despite the experimental differences (e.g., OH and K concentrations, sRF resin lot number, and sRF resin age). In these three inert batch contact cases, the isotherm curves matched well and with the maximum Cs loading likely extending well beyond 0.7 mmol/g dry H-form resin (see Figure 3.14).

4.0 Matrix Conditions Post-Contact Testing

Additional post-contact testing of the aqueous phase was requested by WRPS inclusive of solution density, OH concentration, and water content. A subset of samples was tested as these values were not expected to change based on evaluations of Russell et al. (2014) data. Ten samples were selected for testing, two from each of the following test conditions: 5 M Na/1 M OH, 6.5 M Na/0.1 M OH, 6.5 M Na/1.0 M OH, 8 M Na/0.1 M OH, 8 M Na/1.0 M OH. A range of sample-contacted temperatures were evaluated in this set. The selected samples and results are provided in Table 4.1. The pre-contacted results are also shown for direct comparison to the post-contacted results.

Table 4.1. Comparison of Pre- and Post-Contacted Solution Analysis

	Water Content, %		Density, g/mL		Hydroxide, M	
Sample ID	Pre-Contact	Post-Contact	Pre-Contact	Post-Contact	Pre-Contact	Post-Contact
5-H-2-A-25	68.7	68.9	1.242	1.237	1.01	0.929
5-H-5-B-50	66.9	66.6	1.259	1.257	1.01	0.929
6-L-1-C-50	58.4	58.3	1.331	1.324	0.0985	0.0476
6-L-3-D-35	58.6	58.6	1.327	1.321	0.101	0.0323
6-H-5-D-50	58.9	58.7	1.335	1.323	1.02	NM
6-H-5-E-35	58.4	58.6	1.339	1.330	1.03	0.914
6-H-6-A-50	57.9	57.8	1.340	1.337	1.01	0.924
8-L-1-B-25	53.8	53.7	1.375	1.369	0.0971	0.0320
8-L-3-C-35	53.4	53.4	1.378	1.369	0.0955	0.0324
8-H-5-D-50	53.5	53.2	1.383	1.369	1.01	0.904
8-H-6-E-25	52.4	52.6	1.395	1.391	1.00	0.878

NM = not measured

The solution water content and density were nearly indistinguishable (i.e., within expected experimental error) between the pre- and post-contacted samples. Four of the samples were tested after the 72-hour contact at 50 °C where the possibility of water evaporation was expected to be the highest, each of these samples' water content dropped 0.2 to 0.5%. The water content change for the 25 and 35 °C test samples ranged from +0.4 to -0.3%. The solution density was consistently slightly lower post-contact (average of 0.6%). Note that density was determined by different analysts, in different laboratories, using a significantly different volume (i.e., 1 mL versus 10 mL) and these variabilities may have built in a bias.

The OH concentration changed significantly. The starting 1 M OH concentration dropped approximately 10% post-contact (average of 0.91 M OH, n= 6). The starting 0.1 M OH concentration dropped to approximately 67% post-contact (average of 0.032 M OH, n =3) with the exception of 6-L-1-C-50, which dropped 52% post-contact. This significant OH concentration decrease was attributed to the neutralization process of the H-form resin with the OH in the simulant. The magnitude of the change in the current test is much higher than the OH concentration drop measured by Russell et al. (2014) because Russell et al. (2014) used a higher simulant volume to resin mass phase ratio.

Fiskum et al. (2006a) reported 5.96 milliequivalents per gram (mEq/g) of dry H-form resin; Nash et al. (2006) similarly reported a neutralization capacity of 6.0 ± 0.8 mEq/g of H-form resin each specific to sRF batch 5E-370/641. Using this conversion factor on sRF production lot 1F-370/1392, the equilibrium hydroxide concentration can be calculated in the post-contacted solution according to Equation 4.1.

$$\frac{(OH_i \times V_S) - \left(M_r \times \frac{5.96\ mEq}{g}\right)}{V_S} = OH_f \tag{4.1}$$

where OH_i = initial OH concentration (M),
Vs = volume of simulant (mL),
M_r = mass of dry H-form resin (g), and
OH_f = final OH concentration (M).

The final OH concentration was calculated by applying Equation 4.1 to the test samples, using the measured resin mass and simulant volume. Table 4.2 provides the calculated OH concentration and compares it to the measured equilibrium OH concentration. In general, results agree very well, indicating that the conversion factor of 5.96 mEq H^+/g H-form resin is reasonably applicable to the sRF lot used in this testing. The 6-L-1-C-50 sample was contacted with less resin than the companion low-hydroxide samples and this difference resulted in only a ~50% decreased OH concentration (as opposed to 68% decrease found with the companion low-hydroxide samples). Appendix B provides each sample process conditions (mass of H-form resin and simulant volume) such that the final OH concentration may be calculated.

Table 4.2. Calculated Equilibrium Hydroxide Concentration

Sample ID	Dry H-form resin, g	Simulant, mL	Initial mEq OH^-	Resin mEq H+	Net mEq OH^- after contact	Calc final OH^- conc., M	Ratio meas OH^- /calc OH^-	Phase ratio
5-H-2-A-25	0.2406	25.07	25.32	1.44	23.88	0.952	0.98	104
5-H-5-B-50	0.2122	24.56	24.81	1.27	23.53	0.958	0.97	116
6-L-1-C-50	0.2142	24.26	2.39	1.29	1.10	0.046	1.05	113
6-L-3-D-35	0.2528	23.75	2.40	1.52	0.88	0.037	0.87	94
6-H-5-E-35	0.2527	24.45	25.18	1.52	23.67	0.968	0.94	97
6-H-6-A-50	0.2619	23.94	24.18	1.57	22.61	0.944	0.98	91
8-L-1-B-25	0.2433	22.86	2.22	1.46	0.76	0.033	0.96	94
8-L-3-C-35	0.2399	23.26	2.22	1.44	0.78	0.034	0.96	97
8-H-5-D-50	0.2583	23.95	24.19	1.55	22.64	0.945	0.96	93
8-H-6-E-25	0.2468	22.32	22.32	1.48	20.84	0.934	0.94	90

5.0 Conclusions

Small sRF resin samples were contacted with a simple simulant consisting of variable concentrations of Na, K, Cs, OH^-, NO_3^-, and NO_2^- for 72 hours at 25, 35, and 50 °C. The Cs was measured in the pre- and post-contacted samples so that the Cs loading on the sRF could be calculated at each process condition. A large number of isotherms were developed from these data allowing trends to be observed as functions of matrix and temperature parameters. The following conclusions were developed from the isotherm testing:

- Use of aged resin: Tie back to previous data with the 5 M Na matrix conditions showed that the sRF had maintained its effectiveness since production and aging (i.e., 5 years).
- Sodium effect: There was virtually no difference in cesium loading between 6.5 and 8 M sodium at low cesium concentrations and slightly enhanced cesium loading at 6.5 M Na and high cesium concentrations.
- Potassium effect: The potassium effect varied with cesium concentrations. As potassium concentration increases, cesium loading decreases. However, the potassium effect diminishes as the cesium concentration increases essentially resulting in convergence of isotherms at the highest cesium concentration tested. The K concentration has a greater effect at both lower Cs and Na levels. This is attributable to competition for the resin sites between the K and the Cs.
- Hydroxide effect: The equilibrium hydroxide concentration in these tests were nominally 0.03 M and 0.91 M (from the neutralization of feed matrix hydroxide with the H-form resin). The effect of OH on Cs loading is slightly larger at higher Na levels. The more OH present, the more of a positive effect on the Cs loading is seen.
- Temperature effect: At both 6.5 and 8 M sodium increasing temperature decreased the cesium load capacity, regardless of potassium and hydroxide concentrations. The depression at 8 M Na was slightly enhanced relative to the 6.5 M Na matrix.
- It is recommended that ion exchange column and cycle modeling, that addresses plant constraints, be applied to optimize Cs loading efficiency.

6.0 References

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Appendix A

As-Prepared Composition of Feed Simulant

Appendix A

As-Prepared Composition of Feed Simulant

The complete as-prepared calculated simulant composition is shown in Table A.1 and pictured in Figure A.1. Figure A.1 is similar to Figure 2.3 except the concentration of added nitrite (as $NaNO_2$) to reach the 8 M Na matrix is shown. The nitrate and nitrite anions are expected to behave as spectator anions.

Table A.1. Simulant complete composition, as prepared

Solution ID	Na (M)	K (M)	Cs (M)	OH^- (M)	NO_3^- (M)	NO_2^- (M)
5-H-2-A	4.95	0.00493	5.01E-06	0.986	3.97	0.00
5-H-2-B	4.90	0.00489	5.04E-05	0.977	3.93	0.00
5-H-2-C	4.94	0.00493	4.99E-04	0.985	3.96	0.00
5-H-2-D	4.95	0.00494	5.01E-03	0.987	3.97	0.00
5-H-4-A	4.99	0.0498	4.97E-06	0.994	4.05	0.00
5-H-4-B	4.95	0.0493	5.08E-05	0.985	4.01	0.00
5-H-4-C	4.99	0.0497	4.98E-04	0.993	4.04	0.00
5-H-4-D	5.00	0.0498	4.99E-03	0.994	4.06	0.00
5-H-5-A	4.97	0.348	5.02E-06	0.992	4.33	0.00
5-H-5-B	4.93	0.345	5.12E-05	0.983	4.29	0.00
5-H-5-C	4.97	0.347	4.98E-04	0.991	4.32	0.00
5-H-5-D	4.98	0.348	5.02E-03	0.993	4.34	0.00
6-L-1-A	6.49	0.00	5.03E-06	0.0989	6.39	0.00
6-L-1-B	6.43	0.00	5.07E-05	0.0980	6.33	0.00
6-L-1-C	6.48	0.00	5.05E-04	0.0988	6.38	0.00
6-L-1-D	6.50	0.00	5.02E-03	0.0990	6.40	0.00
6-L-1-E	6.50	0.00	4.99E-02	0.0990	6.45	0.00
6-L-3-A	6.40	0.0345	4.94E-06	0.0987	6.34	0.00
6-L-3-B	6.35	0.0342	5.08E-05	0.0978	6.28	0.00
6-L-3-C	6.40	0.0345	4.96E-04	0.0986	6.33	0.00
6-L-3-D	6.41	0.0346	5.02E-03	0.0988	6.35	0.00
6-L-3-E	6.41	0.0346	5.01E-02	0.0988	6.40	0.00
6-L-5-A	6.39	0.343	4.96E-06	0.0980	6.63	0.00
6-L-5-B	6.33	0.340	5.08E-05	0.0971	6.57	0.00
6-L-5-C	6.38	0.343	4.98E-04	0.0979	6.62	0.00
6-L-5-D	6.39	0.343	5.01E-03	0.0981	6.64	0.00
6-L-5-E	6.39	0.343	5.01E-02	0.0981	6.69	0.00
6-L-6-A	6.41	0.493	4.99E-06	0.0985	6.80	0.00
6-L-6-B	6.35	0.489	5.09E-05	0.0976	6.74	0.00
6-L-6-C	6.40	0.493	4.99E-04	0.0984	6.80	0.00
6-L-6-D	6.42	0.494	4.99E-03	0.0986	6.82	0.00
6-L-6-E	6.42	0.494	4.99E-02	0.0986	6.86	0.00
6-H-1-A	6.42	0.00	4.97E-06	0.984	5.43	0.00
6-H-1-B	6.36	0.00	5.08E-05	0.975	5.38	0.00
6-H-1-C	6.41	0.00	4.98E-04	0.983	5.43	0.00
6-H-1-D	6.42	0.00	4.98E-03	0.985	5.44	0.00
6-H-1-E	6.42	0.00	5.02E-02	0.985	5.49	0.00
6-H-3-A	6.47	0.0349	5.07E-06	0.993	5.51	0.00

Table A.1. (contd)

Solution ID	Na (M)	K (M)	Cs (M)	OH^- (M)	NO_3^- (M)	NO_2^-(M)
6-H-3-B	6.41	0.0346	5.08E-05	0.984	5.46	0.00
6-H-3-C	6.46	0.0349	5.02E-04	0.992	5.50	0.00
6-H-3-D	6.47	0.0350	4.99E-03	0.994	5.52	0.00
6-H-3-E	6.47	0.0350	5.02E-02	0.994	5.57	0.00
6-H-5-A	6.45	0.347	5.00E-06	0.990	5.81	0.00
6-H-5-B	6.39	0.344	5.10E-05	0.981	5.76	0.00
6-H-5-C	6.45	0.347	4.97E-04	0.989	5.80	0.00
6-H-5-D	6.46	0.348	5.02E-03	0.991	5.82	0.00
6-H-5-E	6.46	0.348	5.00E-02	0.991	5.87	0.00
6-H-6-A	6.44	0.496	4.99E-06	0.986	5.95	0.00
6-H-6-B	6.39	0.492	5.08E-05	0.978	5.90	0.00
6-H-6-C	6.44	0.496	4.95E-04	0.985	5.95	0.00
6-H-6-D	6.45	0.497	4.98E-03	0.987	5.96	0.00
6-H-6-E	6.45	0.497	4.98E-02	0.987	6.01	0.00
8-L-1-A	7.99	0.00	4.99E-06	0.0995	5.93	1.96
8-L-1-B	7.91	0.00	5.09E-05	0.0986	5.87	1.94
8-L-1-C	7.98	0.00	4.99E-04	0.0994	5.92	1.96
8-L-1-D	7.99	0.00	4.98E-03	0.0996	5.94	1.96
8-L-1-E	7.99	0.00	4.98E-02	0.0996	5.98	1.96
8-L-3-A	7.99	0.0350	5.00E-06	0.0997	5.96	1.97
8-L-3-B	7.92	0.0347	5.10E-05	0.0988	5.90	1.95
8-L-3-C	7.98	0.0350	4.96E-04	0.0996	5.95	1.97
8-L-3-D	8.00	0.0350	4.99E-03	0.0998	5.97	1.97
8-L-3-E	8.00	0.0350	4.98E-02	0.0998	6.01	1.97
8-L-5-A	8.00	0.349	5.06E-06	0.0998	6.28	1.97
8-L-5-B	7.91	0.345	6.24E-05	0.0987	6.21	1.95
8-L-5-C	7.99	0.349	5.09E-04	0.0997	6.27	1.97
8-L-5-D	8.00	0.350	5.00E-03	0.0999	6.29	1.97
8-L-5-E	8.00	0.350	5.02E-02	0.0999	6.33	1.97
8-L-6-A	7.99	0.499	4.95E-06	0.0997	6.42	1.97
8-L-6-B	7.92	0.495	5.02E-05	0.0988	6.37	1.95
8-L-6-C	7.98	0.499	5.00E-04	0.0996	6.42	1.97
8-L-6-D	8.00	0.500	4.99E-03	0.0998	6.43	1.97
8-L-6-E	8.00	0.500	5.00E-02	0.0998	6.48	1.97
8-H-1-A	8.00	0.00	5.00E-06	0.997	5.25	1.75
8-H-1-B	7.92	0.00	5.04E-05	0.988	5.20	1.74
8-H-1-C	7.99	0.00	4.99E-04	0.996	5.24	1.75
8-H-1-D	8.00	0.00	5.01E-03	0.998	5.26	1.75
8-H-1-E	8.00	0.00	5.02E-02	0.998	5.30	1.75
8-H-3-A	7.99	0.0349	5.03E-06	0.997	5.29	1.74
8-H-3-B	7.92	0.0346	5.03E-05	0.988	5.24	1.73
8-H-3-C	7.98	0.0349	4.99E-04	0.996	5.28	1.74
8-H-3-D	8.00	0.0350	5.01E-03	0.998	5.30	1.74
8-H-3-E	8.00	0.0350	5.02E-02	0.998	5.34	1.74
8-H-5-A	8.00	0.349	5.02E-06	0.997	5.60	1.75
8-H-5-B	7.93	0.346	5.03E-05	0.988	5.55	1.74
8-H-5-C	7.99	0.349	5.03E-04	0.996	5.59	1.75
8-H-5-D	8.01	0.350	5.02E-03	0.998	5.61	1.75
8-H-5-E	8.01	0.350	5.01E-02	0.998	5.65	1.75
8-H-6-A	7.99	0.499	4.95E-06	0.997	5.75	1.75

Table A.1. (contd)

Solution ID	Na (M)	K (M)	Cs (M)	OH^- (M)	NO_3^- (M)	NO_2^-(M)
8-H-6-B	7.92	0.495	5.00E-05	0.988	5.69	1.73
8-H-6-C	7.99	0.499	4.94E-04	0.996	5.74	1.75
8-H-6-D	8.00	0.500	5.00E-03	0.998	5.76	1.75
8-H-6-E	8.00	0.500	5.00E-02	0.998	5.80	1.75

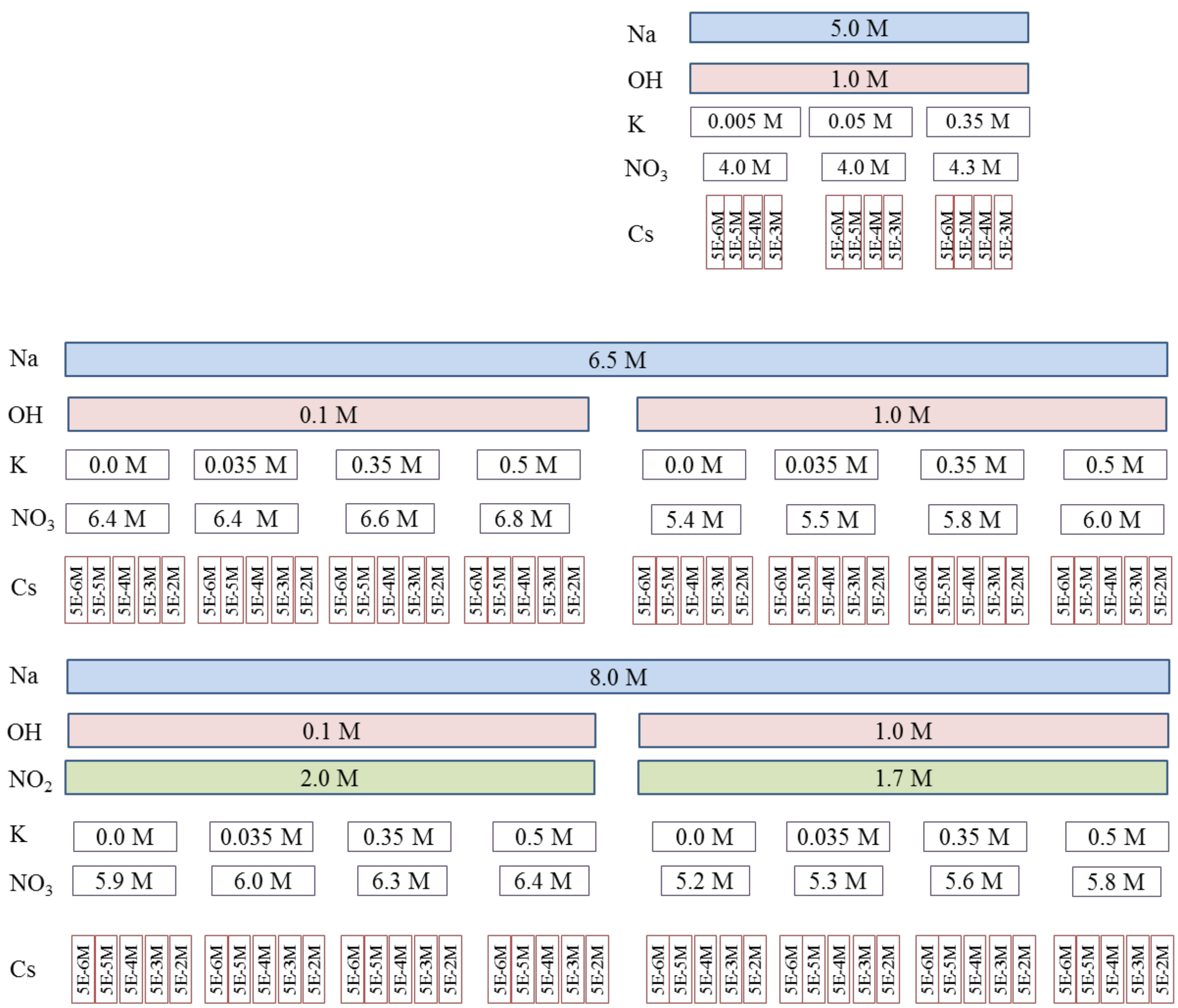

Figure A.1. General Feed Simulant Composition in the Batch Contact Test Matrix

Appendix B

Batch Testing Parameters

Appendix B

Batch Testing Parameters

Table B.1. Datasheet for 50 °C Batch Loading Tests

Sample	Simulant ID Used	Mass of Wet Resin Added	Mass of Dry Resin Added	Mass of Simulant Added	Vol of Simulant Added	Resin Added	Resin Removed
ID No.		(g)	(g)	(g)	(mL)	Date/Time	Date/Time
5-H-2-A-50	5-H-2-A	0.4181	0.2131	30.310	24.41	11/30/15 9:28	12/3/15 9:38
5-H-2-B-50	5-H-2-B	0.4182	0.2131	30.463	24.55	11/30/15 9:30	12/3/15 9:40
5-H-2-C-50	5-H-2-C	0.4173	0.2126	30.145	24.28	11/30/15 9:32	12/3/15 9:41
5-H-2-D-50	5-H-2-D	0.4188	0.2134	30.416	24.50	11/30/15 9:34	12/3/15 9:42
5-H-4-A-50	5-H-4-A	0.4331	0.2207	30.805	24.76	11/30/15 9:35	12/3/15 9:44
5-H-4-B-50	5-H-4-B	0.4171	0.2125	30.332	24.39	11/30/15 9:36	12/3/15 9:45
5-H-4-C-50	5-H-4-C	0.4180	0.2130	30.518	24.49	11/30/15 9:37	12/3/15 9:47
5-H-4-D-50	5-H-4-D	0.4231	0.2156	30.580	24.53	11/30/15 9:39	12/3/15 9:48
5-H-5-A-50	5-H-5-A	0.4210	0.2145	30.945	24.54	11/30/15 9:40	12/3/15 9:50
5-H-5-B-50	5-H-5-B	0.4165	0.2122	30.918	24.56	11/30/15 9:42	12/3/15 9:51
5-H-5-C-50	5-H-5-C	0.4188	0.2134	31.118	24.69	11/30/15 9:45	12/3/15 9:53
5-H-5-D-50	5-H-5-D	0.4187	0.2134	30.924	24.50	11/30/15 9:47	12/3/15 9:54
6-L-1-A-50	6-L-1-A	0.4244	0.2163	32.421	24.04	11/30/15 9:48	12/3/15 9:56
6-L-1-A-50D	6-L-1-A	0.4215	0.2148	32.364	24.00	11/30/15 9:49	12/3/15 9:57
6-L-1-B-50	6-L-1-B	0.4183	0.2132	32.346	24.32	11/30/15 9:51	12/3/15 10:00
6-L-1-B-50D	6-L-1-B	0.4202	0.2141	32.525	24.46	11/30/15 9:53	12/3/15 10:02
6-L-1-C-50	6-L-1-C	0.4203	0.2142	32.296	24.26	11/30/15 9:55	12/3/15 10:03
6-L-1-C-50D	6-L-1-C	0.4198	0.2139	32.602	24.49	11/30/15 9:57	12/3/15 10:05
6-L-1-D-50	6-L-1-D	0.4287	0.2185	32.349	24.29	11/30/15 10:00	12/3/15 10:06
6-L-1-D-50D	6-L-1-D	0.4182	0.2131	32.442	24.36	11/30/15 10:01	12/3/15 10:08
6-L-1-E-50	6-L-1-E	0.4187	0.2134	32.724	24.51	11/30/15 10:04	12/3/15 10:09
6-L-1-E-50D	6-L-1-E	0.4180	0.2130	32.709	24.49	11/30/15 10:06	12/3/15 10:12
6-H-1-A-50	6-H-1-A	0.4227	0.2154	32.394	24.71	11/30/15 10:08	12/3/15 10:14
6-H-1-B-50	6-H-1-B	0.4184	0.2132	32.267	24.66	11/30/15 10:09	12/3/15 10:16
6-H-1-C-50	6-H-1-C	0.4207	0.2144	32.012	24.42	11/30/15 10:11	12/3/15 10:17
6-H-1-D-50	6-H-1-D	0.4244	0.2163	32.334	24.51	11/30/15 10:13	12/3/15 10:19
6-H-1-E-50	6-H-1-E	0.4195	0.2138	32.440	24.65	11/30/15 10:14	12/3/15 10:20
6-L-3-A-50	6-L-3-A	0.4214	0.2147	32.616	24.58	11/30/15 10:16	12/3/15 10:23
6-L-3-B-50	6-L-3-B	0.4215	0.2148	32.428	24.50	11/30/15 10:17	12/3/15 10:25
6-L-3-C-50	6-L-3-C	0.4247	0.2164	32.550	24.55	11/30/15 10:18	12/3/15 10:26
6-L-3-D-50	6-L-3-D	0.4216	0.2148	32.511	24.50	11/30/15 10:19	12/3/15 10:28
6-L-3-E-50	6-L-3-E	0.4211	0.2146	32.527	24.39	11/30/15 10:21	12/3/15 10:30
6-H-3-A-50	6-H-3-A	0.4231	0.2156	31.627	24.02	11/30/15 10:22	12/3/15 10:31

Table B.1. (contd)

Sample ID No.	Simulant ID Used	Mass of Wet Resin Added (g)	Mass of Dry Resin Added (g)	Mass of Simulant Added (g)	Vol of Simulant Added (mL)	Resin Added Date/Time	Resin Removed Date/Time
6-H-3-A-50D	6-H-3-A	0.4207	0.2144	31.702	24.07	11/30/15 10:23	12/3/15 10:33
6-H-3-B-50	6-H-3-B	0.4205	0.2143	31.844	24.21	11/30/15 10:25	12/3/15 10:34
6-H-3-B-50D	6-H-3-B	0.4228	0.2154	31.714	24.11	11/30/15 10:27	12/3/15 10:36
6-H-3-C-50	6-H-3-C	0.4196	0.2138	31.637	24.03	11/30/15 10:29	12/3/15 10:37
6-H-3-C-50D	6-H-3-C	0.4376	0.2230	31.758	24.12	11/30/15 10:30	12/3/15 10:39
6-H-3-D-50	6-H-3-D	0.4198	0.2139	31.722	24.07	11/30/15 10:32	12/3/15 10:40
6-H-3-D-50D	6-H-3-D	0.4223	0.2152	31.697	24.05	11/30/15 10:35	12/3/15 10:42
6-H-3-E-50	6-H-3-E	0.4312	0.2197	31.570	23.87	11/30/15 10:38	12/3/15 10:43
6-H-3-E-50D	6-H-3-E	0.4242	0.2162	31.544	23.85	11/30/15 10:39	12/3/15 10:45
6-L-5-A-50	6-L-5-A	0.4198	0.2139	32.396	24.10	11/30/15 10:47	12/3/15 10:46
6-L-5-B-50	6-L-5-B	0.4196	0.2138	32.480	24.21	11/30/15 10:49	12/3/15 10:48
6-L-5-C-50	6-L-5-C	0.4221	0.2151	32.395	24.09	11/30/15 10:50	12/3/15 10:49
6-L-5-D-50	6-L-5-D	0.4188	0.2134	32.914	24.48	11/30/15 10:51	12/3/15 10:51
6-L-5-E-50	6-L-5-E	0.4247	0.2164	32.770	24.27	11/30/15 10:54	12/3/15 10:52
6-H-5-A-50	6-H-5-A	0.4187	0.2134	32.427	24.34	11/30/15 10:56	12/3/15 10:55
6-H-5-B-50	6-H-5-B	0.4258	0.2170	32.197	24.22	11/30/15 10:37	12/3/15 10:58
6-H-5-C-50	6-H-5-C	0.4205	0.2143	32.372	24.29	11/30/15 10:59	12/3/15 10:59
6-H-5-D-50	6-H-5-D	0.4198	0.2139	32.510	24.36	11/30/15 11:00	12/3/15 11:01
6-H-5-E-50	6-H-5-E	0.4211	0.2146	32.474	24.25	11/30/15 11:03	12/3/15 11:04
6-L-6-A-50	6-L-6-A	0.4195	0.2138	32.889	24.29	11/30/15 11:06	12/3/15 11:05
6-L-6-B-50	6-L-6-B	0.4245	0.2163	33.045	24.44	11/30/15 11:08	12/3/15 11:08
6-L-6-C-50	6-L-6-C	0.4184	0.2132	33.005	24.39	11/30/15 11:11	12/3/15 11:09
6-L-6-D-50	6-L-6-D	0.4207	0.2144	32.775	24.19	11/30/15 11:12	12/3/15 11:11
6-L-6-E-50	6-L-6-E	0.4218	0.2149	33.164	24.44	11/30/15 11:13	12/3/15 11:13
6-H-6-A-50	6-H-6-A	0.4513	0.2619	32.083	23.94	12/4/15 9:15	12/7/15 9:49
6-H-6-B-50	6-H-6-B	0.4459	0.2588	32.338	24.20	12/4/15 9:17	12/7/15 9:50
6-H-6-C-50	6-H-6-C	0.4432	0.2572	31.995	23.89	12/4/15 9:29	12/7/15 9:51
6-H-6-D-50	6-H-6-D	0.4478	0.2599	32.152	23.98	12/4/15 9:32	12/7/15 9:53
6-H-6-E-50	6-H-6-E	0.4502	0.2613	32.426	24.13	12/4/15 9:33	12/7/15 9:55
8-L-1-A-50	8-L-1-A	0.4448	0.2582	32.862	23.87	12/4/15 9:35	12/7/15 9:57
8-L-1-B-50	8-L-1-B	0.4487	0.2604	32.939	23.95	12/4/15 9:36	12/7/15 9:59
8-L-1-C-50	8-L-1-C	0.4481	0.2601	32.725	23.80	12/4/15 9:38	12/7/15 10:00
8-L-1-D-50	8-L-1-D	0.4451	0.2583	33.075	24.02	12/4/15 9:39	12/7/15 10:02
8-L-1-E-50	8-L-1-E	0.4517	0.2622	33.004	23.89	12/4/15 9:40	12/7/15 10:03
8-H-1-A-50	8-H-1-A	0.4524	0.2626	32.539	23.93	12/4/15 9:43	12/7/15 10:05
8-H-1-B-50	8-H-1-B	0.4578	0.2657	32.375	23.87	12/4/15 9:44	12/7/15 10:07
8-H-1-C-50	8-H-1-C	0.4480	0.2600	32.573	23.97	12/4/15 9:46	12/7/15 10:08
8-H-1-D-50	8-H-1-D	0.4500	0.2612	32.325	23.73	12/4/15 9:48	12/7/15 10:10
8-H-1-E-50	8-H-1-E	0.4542	0.2636	32.483	23.75	12/4/15 9:49	12/7/15 10:12
8-L-3-A-50	8-L-3-A	0.4668	0.2709	32.507	23.63	12/4/15 9:51	12/7/15 10:13
8-L-3-B-50	8-L-3-B	0.4452	0.2584	32.703	23.78	12/4/15 9:55	12/7/15 10:15
8-L-3-C-50	8-L-3-C	0.4507	0.2616	33.036	23.98	12/4/15 9:57	12/7/15 10:16

Table B.1. (contd)

Sample ID No.	Simulant ID Used	Mass of Wet Resin Added (g)	Mass of Dry Resin Added (g)	Mass of Simulant Added (g)	Vol of Simulant Added (mL)	Resin Added Date/Time	Resin Removed Date/Time
8-L-3-D-50	8-L-3-D	0.4516	0.2621	32.717	23.77	12/4/15 9:58	12/7/15 10:18
8-L-3-E-50	8-L-3-E	0.4424	0.2568	32.865	23.81	12/4/15 9:59	12/7/15 10:19
8-H-3-A-50	8-H-3-A	0.4434	0.2573	32.558	23.85	12/4/15 10:00	12/7/15 10:22
8-H-3-B-50	8-H-3-B	0.4517	0.2622	32.417	23.80	12/4/15 10:02	12/7/15 10:23
8-H-3-C-50	8-H-3-C	0.4463	0.2590	32.414	23.76	12/4/15 10:20	12/7/15 10:25
8-H-3-D-50	8-H-3-D	0.4418	0.2564	32.717	23.99	12/4/15 10:22	12/7/15 10:26
8-H-3-E-50	8-H-3-E	0.4553	0.2643	32.784	23.98	12/4/15 10:23	12/7/15 10:28
8-L-5-A-50	8-L-5-A	0.4502	0.2613	33.179	23.79	12/4/15 10:26	12/7/15 10:29
8-L-5-A-50D	8-L-5-A	0.4472	0.2596	33.193	23.80	12/4/15 10:27	12/7/15 10:31
8-L-5-B-50	8-L-5-B	0.4439	0.2576	33.434	24.04	12/4/15 10:31	12/7/15 10:33
8-L-5-B-50D	8-L-5-B	0.4507	0.2616	33.333	23.97	12/4/15 10:32	12/7/15 10:34
8-L-5-C-50	8-L-5-C	0.4467	0.2593	33.339	23.93	12/4/15 10:34	12/7/15 10:36
8-L-5-C-50D	8-L-5-C	0.4471	0.2595	33.341	23.93	12/4/15 10:37	12/7/15 10:37
8-L-5-D-50	8-L-5-D	0.4541	0.2636	33.469	24.02	12/4/15 10:41	12/7/15 10:38
8-L-5-D-50D	8-L-5-D	0.4498	0.2611	33.331	23.92	12/4/15 10:47	12/7/15 10:40
8-L-5-E-50	8-L-5-E	0.4499	0.2611	33.442	23.90	12/4/15 10:48	12/7/15 10:43
8-L-5-E-50D	8-L-5-E	0.4448	0.2582	33.411	23.88	12/4/15 10:50	12/7/15 10:44
8-H-5-A-50	8-H-5-A	0.4423	0.2567	33.684	24.33	12/4/15 10:51	12/7/15 10:46
8-H-5-B-50	8-H-5-B	0.4490	0.2606	32.821	23.78	12/4/15 10:53	12/7/15 10:47
8-H-5-C-50	8-H-5-C	0.4454	0.2585	33.003	23.89	12/4/15 10:54	12/7/15 10:49
8-H-5-D-50	8-H-5-D	0.4450	0.2583	33.128	23.95	12/4/15 10:55	12/7/15 10:50
8-H-5-E-50	8-H-5-E	0.4548	0.2640	32.373	23.38	12/4/15 10:56	12/7/15 10:52
8-L-6-A-50	8-L-6-A	0.4505	0.2615	33.622	23.98	12/4/15 10:58	12/7/15 10:53
8-L-6-B-50	8-L-6-B	0.4508	0.2616	33.557	23.96	12/4/15 11:00	12/7/15 10:55
8-L-6-C-50	8-L-6-C	0.4438	0.2576	33.513	23.91	12/4/15 11:01	12/7/15 10:56
8-L-6-D-50	8-L-6-D	0.4516	0.2621	33.633	23.98	12/4/15 11:03	12/7/15 10:58
8-L-6-E-50	8-L-6-E	0.4506	0.2615	33.678	23.89	12/4/15 11:04	12/7/15 10:59
8-H-6-A-50	8-H-6-A	0.4544	0.2637	33.105	23.84	12/4/15 11:06	12/7/15 11:02
8-H-6-A-50D	8-H-6-A	0.4415	0.2562	32.941	23.72	12/4/15 11:08	12/7/15 11:03
8-H-6-B-50	8-H-6-B	0.4430	0.2571	32.753	23.63	12/4/15 11:11	12/7/15 11:06
8-H-6-B-50D	8-H-6-B	0.4563	0.2648	32.519	23.46	12/4/15 11:12	12/7/15 11:07
8-H-6-C-50	8-H-6-C	0.4423	0.2567	32.715	23.57	12/4/15 11:14	12/7/15 11:08
8-H-6-C-50D	8-H-6-C	0.4488	0.2605	32.603	23.49	12/4/15 11:15	12/7/15 11:10
8-H-6-D-50	8-H-6-D	0.4401	0.2554	32.639	23.49	12/4/15 11:17	12/7/15 11:12
8-H-6-D-50D	8-H-6-D	0.4465	0.2591	32.487	23.38	12/4/15 11:18	12/7/15 11:13
8-H-6-E-50	8-H-6-E	0.4553	0.2643	32.711	23.45	12/4/15 11:19	12/7/15 11:15
8-H-6-E-50D	8-H-6-E	0.4448	0.2582	32.654	23.41	12/4/15 11:22	12/7/15 11:16

Table B.2. Datasheet for 35°C Batch Loading Tests

Sample ID No.	Simulant ID Used	Mass of Wet Resin Added (g)	Mass of Dry Resin Added (g)	Mass of Simulant Added (g)	Vol of Simulant Added (mL)	Resin Added Date/Time	Resin Removed Date/Time
5-H-2-A-35	5-H-2-A	0.5006	0.2500	29.878	24.06	11/20/15 8:32	11/23/15 9:36
5-H-2-B-35	5-H-2-B	0.4971	0.2483	29.503	23.77	11/20/15 8:34	11/23/15 9:38
5-H-2-C-35	5-H-2-C	0.5113	0.2554	29.600	23.84	11/20/15 8:35	11/23/15 9:39
5-H-2-D-35	5-H-2-D	0.5009	0.2502	29.349	23.64	11/20/15 8:37	11/23/15 9:40
5-H-4-A-35	5-H-4-A	0.4977	0.2486	29.366	23.60	11/20/15 8:39	11/23/15 9:42
5-H-4-B-35	5-H-4-B	0.5044	0.2519	29.708	23.89	11/20/15 8:40	11/23/15 9:44
5-H-4-C-35	5-H-4-C	0.4952	0.2473	29.810	23.92	11/20/15 8:42	11/23/15 9:47
5-H-4-D-35	5-H-4-D	0.4917	0.2456	30.120	24.16	11/20/15 8:43	11/23/15 9:49
5-H-5-A-35	5-H-5-A	0.5005	0.2500	29.720	23.57	11/20/15 8:45	11/23/15 9:51
5-H-5-B-35	5-H-5-B	0.4964	0.2479	30.618	24.33	11/20/15 8:47	11/23/15 9:53
5-H-5-C-35	5-H-5-C	0.5001	0.2498	30.001	23.80	11/20/15 8:48	11/23/15 9:55
5-H-5-D-35	5-H-5-D	0.5021	0.2508	30.237	23.95	11/20/15 8:50	11/23/15 9:57
6-L-1-A-35	6-L-1-A	0.5012	0.2503	29.106	21.58	11/20/15 11:48	11/23/15 9:58
6-L-1-A-35D	6-L-1-A	0.5051	0.2523	31.428	23.30	11/20/15 8:54	11/23/15 10:00
6-L-1-B-35	6-L-1-B	0.5025	0.2510	31.556	23.73	11/20/15 8:56	11/23/15 10:02
6-L-1-B-35D	6-L-1-B	0.5019	0.2507	31.551	23.72	11/20/15 8:56	11/23/15 10:04
6-L-1-C-35	6-L-1-C	0.4991	0.2493	31.343	23.55	11/20/15 9:09	11/23/15 10:06
6-L-1-C-35D	6-L-1-C	0.5054	0.2524	31.259	23.49	11/20/15 9:10	11/23/15 10:07
6-L-1-D-35	6-L-1-D	0.4991	0.2493	31.687	23.79	11/20/15 9:12	11/23/15 10:08
6-L-1-D-35D	6-L-1-D	0.5079	0.2537	31.616	23.74	11/20/15 9:14	11/23/15 10:11
6-L-1-E-35	6-L-1-E	0.4982	0.2488	31.799	23.81	11/20/15 9:15	11/23/15 10:12
6-L-1-E-35D	6-L-1-E	0.4979	0.2487	31.991	23.96	11/20/15 9:17	11/23/15 10:14
6-H-1-A-35	6-H-1-A	0.5073	0.2534	31.477	24.01	11/20/15 9:19	11/23/15 10:16
6-H-1-B-35	6-H-1-B	0.5045	0.2520	30.991	23.68	11/20/15 9:20	11/23/15 10:17
6-H-1-C-35	6-H-1-C	0.5050	0.2522	31.081	23.71	11/20/15 9:22	11/23/15 10:19
6-H-1-D-35	6-H-1-D	0.5000	0.2497	31.527	23.90	11/20/15 9:24	11/23/15 10:20
6-H-1-E-35	6-H-1-E	0.5021	0.2508	31.521	23.95	11/20/15 9:25	11/23/15 10:22
6-L-3-A-35	6-L-3-A	0.5028	0.2511	31.903	24.04	11/20/15 9:27	11/23/15 10:23
6-L-3-B-35	6-L-3-B	0.5021	0.2508	31.662	23.92	11/20/15 9:28	11/23/15 10:24
6-L-3-C-35	6-L-3-C	0.5113	0.2554	31.610	23.84	11/20/15 9:29	11/23/15 10:26
6-L-3-D-35	6-L-3-D	0.5061	0.2528	31.517	23.75	11/20/15 9:31	11/23/15 10:27
6-L-3-E-35	6-L-3-E	0.5002	0.2498	27.260	20.44	11/20/15 9:32	11/23/15 10:29
6-H-3-A-35	6-H-3-A	0.4954	0.2474	31.902	24.22	11/20/15 9:33	11/23/15 10:30
6-H-3-A-35D	6-H-3-A	0.5132	0.2563	31.982	24.28	11/20/15 9:35	11/23/15 10:31
6-H-3-B-35	6-H-3-B	0.5021	0.2508	31.978	24.31	11/20/15 9:36	11/23/15 10:33
6-H-3-B-35D	6-H-3-B	0.5000	0.2497	31.876	24.23	11/20/15 9:37	11/23/15 10:35
6-H-3-C-35	6-H-3-C	0.4994	0.2494	32.584	24.75	11/20/15 9:39	11/23/15 10:37
6-H-3-C-35D	6-H-3-C	0.5004	0.2499	32.410	24.62	11/20/15 9:40	11/23/15 10:39
6-H-3-D-35	6-H-3-D	0.5100	0.2547	32.593	24.73	11/20/15 9:41	11/23/15 10:40

Table B.2. (contd)

Sample ID No.	Simulant ID Used	Mass of Wet Resin Added (g)	Mass of Dry Resin Added (g)	Mass of Simulant Added (g)	Vol of Simulant Added (mL)	Resin Added Date/Time	Resin Removed Date/Time
6-H-3-D-35D	6-H-3-D	0.5042	0.2518	32.581	24.72	11/20/15 9:43	11/23/15 10:41
6-H-3-E-35	6-H-3-E	0.5014	0.2504	32.716	24.74	11/20/15 11:14	11/23/15 10:43
6-H-3-E-35D	6-H-3-E	0.4968	0.2481	32.706	24.73	11/20/15 11:15	11/23/15 10:45
6-L-5-A-35	6-L-5-A	0.5085	0.2540	33.137	24.65	11/20/15 11:16	11/23/15 10:47
6-L-5-B-35	6-L-5-B	0.5003	0.2499	33.069	24.65	11/20/15 11:17	11/23/15 10:48
6-L-5-C-35	6-L-5-C	0.2491	0.1244	20.233	15.04	12/08/15 9:44	12/11/15 10:02
6-L-5-D-35	6-L-5-D	0.5036	0.2515	32.524	24.19	11/20/15 11:31	11/23/15 10:53
6-L-5-E-35	6-L-5-E	0.5131	0.2563	32.884	24.36	11/20/15 11:32	11/23/15 10:54
6-H-5-A-35	6-H-5-A	0.5038	0.2516	32.401	24.32	11/20/15 11:34	11/23/15 10:56
6-H-5-B-35	6-H-5-B	0.5122	0.2558	32.488	24.44	11/20/15 11:35	11/23/15 10:57
6-H-5-C-35	6-H-5-C	0.5117	0.2556	32.552	24.42	11/20/15 11:36	11/23/15 10:59
6-H-5-D-35	6-H-5-D	0.5014	0.2504	32.436	24.31	11/20/15 11:37	11/23/15 11:01
6-H-5-E-35	6-H-5-E	0.5060	0.2527	32.743	24.45	11/20/15 11:39	11/23/15 11:02
6-L-6-A-35	6-L-6-A	0.5000	0.2497	32.936	24.33	11/20/15 11:40	11/23/15 11:04
6-L-6-B-35	6-L-6-B	0.5054	0.2524	32.920	24.35	11/20/15 11:41	11/23/15 11:06
6-L-6-C-35	6-L-6-C	0.5030	0.2512	32.911	24.32	11/20/15 11:43	11/23/15 11:07
6-L-6-D-35	6-L-6-D	0.4990	0.2492	32.933	24.31	11/20/15 11:44	11/23/15 11:09
6-L-6-E-35	6-L-6-E	0.5012	0.2503	33.110	24.40	11/20/15 11:45	11/23/15 11:11
6-H-6-A-35	6-H-6-A	0.4151	0.2424	32.142	23.98	12/8/15 8:57	12/11/15 9:09
6-H-6-B-35	6-H-6-B	0.4128	0.2411	31.000	23.20	12/8/15 8:59	12/11/15 9:12
6-H-6-C-35	6-H-6-C	0.4095	0.2391	32.037	23.92	12/8/15 9:00	12/11/15 9:14
6-H-6-D-35	6-H-6-D	0.4113	0.2402	30.979	23.11	12/8/15 9:02	12/11/15 9:16
6-H-6-E-35	6-H-6-E	0.4140	0.2418	31.068	23.12	12/8/15 9:04	12/11/15 9:17
8-L-1-A-35	8-L-1-A	0.4134	0.2414	31.839	23.13	12/8/15 9:08	12/11/15 9:21
8-L-1-B-35	8-L-1-B	0.4142	0.2419	31.639	23.01	12/8/15 9:06	12/11/15 9:22
8-L-1-C-35	8-L-1-C	0.4139	0.2417	32.188	23.41	12/8/15 9:09	12/11/15 9:24
8-L-1-D-35	8-L-1-D	0.4225	0.2467	32.008	23.25	12/8/15 9:11	12/11/15 9:26
8-L-1-E-35	8-L-1-E	0.4128	0.2411	32.147	23.27	12/8/15 9:13	12/11/15 9:27
8-H-1-A-35	8-H-1-A	0.4143	0.2419	31.488	23.16	12/8/15 9:17	12/11/15 9:30
8-H-1-B-35	8-H-1-B	0.4112	0.2401	31.577	23.28	12/8/15 9:19	12/11/15 9:32
8-H-1-C-35	8-H-1-C	0.4118	0.2405	31.695	23.32	12/8/15 9:21	12/11/15 9:34
8-H-1-D-35	8-H-1-D	0.4147	0.2422	31.710	23.28	12/8/15 9:22	12/11/15 9:35
8-H-1-E-35	8-H-1-E	0.4137	0.2416	31.548	23.07	12/8/15 9:25	12/11/15 9:38
8-L-3-A-35	8-L-3-A	0.4122	0.2407	31.876	23.17	12/8/15 9:26	12/11/15 9:40
8-L-3-B-35	8-L-3-B	0.4132	0.2413	31.561	22.95	12/8/15 9:28	12/11/15 9:42
8-L-3-C-35	8-L-3-C	0.4108	0.2399	32.041	23.26	12/8/15 9:29	12/11/15 9:44
8-L-3-D-35	8-L-3-D	0.4131	0.2412	32.105	23.32	12/8/15 9:31	12/11/15 9:46
8-L-3-E-35	8-L-3-E	0.4122	0.2407	32.331	23.42	12/8/15 9:32	12/11/15 9:50
8-H-3-A-35	8-H-3-A	0.4178	0.2440	31.869	23.34	12/8/15 9:33	12/11/15 9:51
8-H-3-B-35	8-H-3-B	0.4108	0.2399	31.599	23.20	12/8/15 9:35	12/11/15 9:53
8-H-3-C-35	8-H-3-C	0.4074	0.2379	31.655	23.20	12/8/15 9:38	12/11/15 9:56

Table B.2. (contd)

Sample	Simulant ID Used	Mass of Wet Resin Added	Mass of Dry Resin Added	Mass of Simulant Added	Vol of Simulant Added	Resin Added	Resin Removed
ID No.		(g)	(g)	(g)	(mL)	Date/Time	Date/Time
8-H-3-D-35	8-H-3-D	0.4132	0.2413	31.616	23.18	12/8/15 9:40	12/11/15 9:58
8-H-3-E-35	8-H-3-E	0.4162	0.2430	31.535	23.06	12/8/15 9:42	12/11/15 10:00
8-L-5-A-35	8-L-5-A	0.4131	0.2412	31.970	22.93	12/8/15 9:46	12/11/15 10:05
8-L-5-A-35D	8-L-5-A	0.4222	0.2465	31.921	22.89	12/8/15 9:47	12/11/15 10:07
8-L-5-B-35	8-L-5-B	0.4146	0.2421	31.758	22.83	12/8/15 9:48	12/11/15 10:09
8-L-5-B-35D	8-L-5-B	0.4153	0.2425	31.686	22.78	12/8/15 9:50	12/11/15 10:11
8-L-5-C-35	8-L-5-C	0.4140	0.2418	31.787	22.82	12/8/15 9:51	12/11/15 10:13
8-L-5-C-35D	8-L-5-C	0.4127	0.2410	31.417	22.55	12/8/15 9:52	12/11/15 10:14
8-L-5-D-35	8-L-5-D	0.4189	0.2446	31.493	22.60	12/8/15 9:54	12/11/15 10:18
8-L-5-D-35D	8-L-5-D	0.4113	0.2402	31.429	22.56	12/8/15 9:56	12/11/15 10:19
8-L-5-E-35	8-L-5-E	0.4113	0.2402	31.273	22.35	12/8/15 9:57	12/11/15 10:23
8-L-5-E-35D	8-L-5-E	0.4173	0.2437	31.203	22.30	12/8/15 9:59	12/11/15 10:26
8-H-5-A-35	8-H-5-A	0.4165	0.2432	30.226	21.83	12/8/15 10:01	12/11/15 10:28
8-H-5-B-35	8-H-5-B	0.4229	0.2470	30.122	21.83	12/8/15 10:02	12/11/15 10:30
8-H-5-C-35	8-H-5-C	0.4103	0.2396	30.278	21.92	12/8/15 10:04	12/11/15 10:32
8-H-5-D-35	8-H-5-D	0.4177	0.2439	30.154	21.80	12/8/15 10:06	12/11/15 10:34
8-H-5-E-35	8-H-5-E	0.4133	0.2414	30.086	21.73	12/8/15 10:07	12/11/15 10:36
8-L-6-A-35	8-L-6-A	0.4104	0.2397	30.014	21.41	12/8/15 10:10	12/11/15 10:38
8-L-6-B-35	8-L-6-B	0.4145	0.2421	29.832	21.30	12/8/15 10:11	12/11/15 10:40
8-L-6-C-35	8-L-6-C	0.4118	0.2405	29.901	21.33	12/8/15 10:14	12/11/15 10:42
8-L-6-D-35	8-L-6-D	0.4116	0.2404	29.983	21.38	12/8/15 10:16	12/11/15 10:43
8-L-6-E-35	8-L-6-E	0.4169	0.2435	29.816	21.15	12/8/15 10:19	12/11/15 10:45
8-H-6-A-35	8-H-6-A	0.4106	0.2398	28.618	20.61	12/8/15 10:23	12/11/15 10:46
8-H-6-A-35D	8-H-6-A	0.4100	0.2394	28.947	20.85	12/8/15 10:28	12/11/15 10:48
8-H-6-B-35	8-H-6-B	0.4138	0.2416	30.953	22.33	12/8/15 10:29	12/11/15 11:01
8-H-6-B-35D	8-H-6-B	0.4163	0.2431	29.980	21.63	12/8/15 10:31	12/11/15 11:03
8-H-6-C-35	8-H-6-C	0.4117	0.2404	31.696	22.84	12/8/15 10:34	12/11/15 11:05
8-H-6-C-35D	8-H-6-C	0.4137	0.2416	31.495	22.70	12/8/15 10:36	12/11/15 11:07
8-H-6-D-35	8-H-6-D	0.4212	0.2460	31.073	22.36	12/8/15 10:37	12/11/15 11:08
8-H-6-D-35D	8-H-6-D	0.4119	0.2405	29.852	21.48	12/8/15 10:39	12/11/15 11:10
8-H-6-E-35	8-H-6-E	0.4124	0.2408	29.410	21.08	12/8/15 10:40	12/11/15 11:11
8-H-6-E-35D	8-H-6-E	0.4180	0.2441	29.498	21.14	12/8/15 10:41	12/11/15 11:13

Table B.3. Datasheet for 25 °C Batch Loading Tests

Sample ID No.	Simulant ID Used	Mass of Wet Resin Added (g)	Mass of Dry Resin Added (g)	Mass of Simulant Added (g)	Vol of Simulant Added (mL)	Resin Added Date/Time	Resin Removed Date/Time
5-H-2-A-25	5-H-2-A	0.5542	0.2406	31.141	25.07	11/16/15 10:45	11/19/15 11:01
5-H-2-B-25	5-H-2-B	0.5539	0.2405	30.958	24.94	11/16/15 10:46	11/19/15 11:04
5-H-2-C-25	5-H-2-C	0.5544	0.2407	31.089	25.04	11/16/15 10:48	11/19/15 11:06
5-H-2-D-25	5-H-2-D	0.5561	0.2414	30.949	24.93	11/16/15 10:49	11/19/15 11:07
5-H-4-A-25	5-H-4-A	0.5587	0.2425	30.972	24.89	11/16/15 10:51	11/19/15 11:09
5-H-4-B-25	5-H-4-B	0.5573	0.2419	30.929	24.87	11/16/15 10:53	11/19/15 11:10
5-H-4-C-25	5-H-4-C	0.5598	0.2430	30.367	24.37	11/16/15 10:54	11/19/15 11:12
5-H-4-D-25	5-H-4-D	0.5547	0.2408	31.070	24.92	11/16/15 10:55	11/19/15 11:16
5-H-5-A-25	5-H-5-A	0.5556	0.2412	31.351	24.86	11/16/15 10:57	11/19/15 11:18
5-H-5-B-25	5-H-5-B	0.5545	0.2407	30.728	24.41	11/16/15 10:58	11/19/15 11:20
5-H-5-C-25	5-H-5-C	0.5535	0.2403	31.221	24.77	11/16/15 11:00	11/19/15 11:22
5-H-5-D-25	5-H-5-D	0.5539	0.2405	31.369	24.85	11/16/15 11:01	11/19/15 11:24
6-L-1-A-25	6-L-1-A	0.5575	0.2420	33.052	25.08	11/16/15 11:02	11/19/15 11:25
6-L-1-A-25D	6-L-1-A	0.5532	0.2402	33.204	25.19	11/16/15 11:04	11/19/15 11:27
6-L-1-B-25	6-L-1-B	0.5597	0.2430	32.982	24.80	11/16/15 11:05	11/19/15 11:28
6-L-1-B-25D	6-L-1-B	0.5568	0.2417	32.939	24.77	11/16/15 11:06	11/19/15 11:30
6-L-1-C-25	6-L-1-C	0.5565	0.2416	32.697	24.57	11/16/15 11:08	11/19/15 11:32
6-L-1-C-25D	6-L-1-C	0.5586	0.2425	32.718	24.58	11/16/15 11:09	11/19/15 11:34
6-L-1-D-25	6-L-1-D	0.5532	0.2402	32.977	24.76	11/16/15 11:11	11/19/15 11:35
6-L-1-D-25D	6-L-1-D	0.5574	0.2420	32.975	24.76	11/16/15 11:12	11/19/15 11:37
6-L-1-E-25	6-L-1-E	0.5578	0.2422	33.059	24.76	11/16/15 11:14	11/19/15 11:39
6-L-1-E-25D	6-L-1-E	0.5560	0.2414	33.161	24.83	11/16/15 11:15	11/19/15 11:41
6-H-1-A-25	6-H-1-A	0.5583	0.2424	32.232	24.59	11/16/15 11:17	11/19/15 11:43
6-H-1-B-25	6-H-1-B	0.5523	0.2398	32.323	24.70	11/16/15 11:19	11/19/15 11:45
6-H-1-C-25	6-H-1-C	0.5552	0.2410	32.517	24.81	11/16/15 11:21	11/19/15 11:46
6-H-1-D-25	6-H-1-D	0.5558	0.2413	32.393	24.56	11/16/15 11:23	11/19/15 11:48
6-H-1-E-25	6-H-1-E	0.5555	0.2412	32.716	24.85	11/16/15 11:25	11/19/15 11:50
6-L-3-A-25	6-L-3-A	0.5602	0.2432	32.133	24.21	11/16/15 11:26	11/19/15 11:53
6-L-3-B-25	6-L-3-B	0.5598	0.2430	32.772	24.76	11/16/15 11:28	11/19/15 11:56
6-L-3-C-25	6-L-3-C	0.5556	0.2412	32.919	24.83	11/16/15 11:29	11/19/15 11:59
6-L-3-D-25	6-L-3-D	0.5538	0.2404	32.990	24.86	11/16/15 11:31	11/19/15 12:01
6-L-3-E-25	6-L-3-E	0.5528	0.2400	32.938	24.70	11/16/15 11:34	11/19/15 12:03
6-H-3-A-25	6-H-3-A	0.5523	0.2398	32.651	24.79	11/16/15 11:35	11/19/15 12:04
6-H-3-A-25D	6-H-3-A	0.5594	0.2428	32.706	24.83	11/16/15 11:37	11/19/15 12:06
6-H-3-B-25	6-H-3-B	0.5540	0.2405	32.564	24.75	11/16/15 11:40	11/19/15 12:08
6-H-3-B-25D	6-H-3-B	0.5525	0.2399	32.529	24.73	11/16/15 11:42	11/19/15 12:12
6-H-3-C-25	6-H-3-C	0.5586	0.2425	32.691	24.83	11/16/15 11:45	11/19/15 12:13
6-H-3-C-25D	6-H-3-C	0.5549	0.2409	32.541	24.72	11/16/15 11:47	11/19/15 12:15
6-H-3-D-25	6-H-3-D	0.5585	0.2425	32.592	24.73	11/16/15 11:48	11/19/15 12:18

Table B.3. (contd)

Sample ID No.	Simulant ID Used	Mass of Wet Resin Added (g)	Mass of Dry Resin Added (g)	Mass of Simulant Added (g)	Vol of Simulant Added (mL)	Resin Added Date/Time	Resin Removed Date/Time
6-H-3-D-25D	6-H-3-D	0.5511	0.2392	32.616	24.75	11/16/15 11:49	11/19/15 12:21
6-H-3-E-25	6-H-3-E	0.5589	0.2426	32.774	24.78	11/16/15 11:51	11/19/15 12:23
6-H-3-E-25D	6-H-3-E	0.5504	0.2389	32.858	24.84	11/16/15 11:52	11/19/15 12:26
6-L-5-A-25	6-L-5-A	0.5569	0.2418	32.663	24.30	11/16/15 11:54	11/19/15 12:28
6-L-5-B-25	6-L-5-B	0.5595	0.2429	33.327	24.84	11/16/15 11:55	11/19/15 12:29
6-L-5-C-25	6-L-5-C	0.5573	0.2419	33.215	24.70	11/16/15 11:56	11/19/15 12:31
6-L-5-D-25	6-L-5-D	0.5624	0.2442	33.305	24.77	11/16/15 11:57	11/19/15 12:32
6-L-5-E-25	6-L-5-E	0.5503	0.2389	33.423	24.76	11/16/15 11:59	11/19/15 12:34
6-H-5-A-25	6-H-5-A	0.5509	0.2392	33.005	24.78	11/16/15 12:00	11/19/15 12:36
6-H-5-B-25	6-H-5-B	0.5552	0.2410	32.981	24.81	11/16/15 12:04	11/19/15 12:38
6-H-5-C-25	6-H-5-C	0.5521	0.2397	32.952	24.72	11/16/15 12:05	11/19/15 12:39
6-H-5-D-25	6-H-5-D	0.5588	0.2426	33.003	24.73	11/16/15 12:07	11/19/15 12:41
6-H-5-E-25	6-H-5-E	0.5509	0.2392	32.966	24.61	11/16/15 12:10	11/19/15 12:42
6-L-6-A-25	6-L-6-A	0.5583	0.2424	33.262	24.57	11/16/15 12:14	11/19/15 12:44
6-L-6-B-25	6-L-6-B	0.5655	0.2455	33.261	24.60	11/16/15 12:15	11/19/15 12:46
6-L-6-C-25	6-L-6-C	0.5546	0.2408	32.504	24.02	11/16/15 12:16	11/19/15 12:48
6-L-6-D-25	6-L-6-D	0.5515	0.2394	33.558	24.77	11/16/15 12:19	11/19/15 12:50
6-L-6-E-25	6-L-6-E	0.5585	0.2425	33.755	24.88	11/16/15 12:21	11/19/15 12:51
6-H-6-A-25	6-H-6-A	0.3517	0.2456	32.445	24.21	12/14/15 9:13	12/17/15 9:05
6-H-6-B-25	6-H-6-B	0.3547	0.2477	32.421	24.26	12/14/15 9:15	12/17/15 9:06
6-H-6-C-25	6-H-6-C	0.3583	0.2502	32.424	24.21	12/14/15 9:16	12/17/15 9:08
6-H-6-D-25	6-H-6-D	0.3479	0.2430	31.657	23.61	12/14/15 9:17	12/17/15 9:11
6-H-6-E-25	6-H-6-E	0.3484	0.2433	32.001	23.81	12/14/15 9:19	12/17/15 9:16
8-L-1-A-25	8-L-1-A	0.3504	0.2447	31.775	23.08	12/14/15 9:21	12/17/15 9:19
8-L-1-B-25	8-L-1-B	0.3484	0.2433	31.442	22.86	12/14/15 9:23	12/17/15 9:20
8-L-1-C-25	8-L-1-C	0.3502	0.2446	31.326	22.78	12/14/15 9:25	12/17/15 9:22
8-L-1-D-25	8-L-1-D	0.3509	0.2451	29.020	21.08	12/14/15 9:27	12/17/15 9:23
8-L-1-E-25	8-L-1-E	0.3516	0.2456	29.408	21.28	12/14/15 9:29	12/17/15 9:25
8-H-1-A-25	8-H-1-A	0.3471	0.2424	28.969	21.31	12/14/15 9:31	12/17/15 9:27
8-H-1-B-25	8-H-1-B	0.3544	0.2475	26.481	19.52	12/14/15 9:33	12/17/15 9:30
8-H-1-C-25	8-H-1-C	0.3507	0.2449	28.385	20.89	12/14/15 9:35	12/17/15 9:32
8-H-1-D-25	8-H-1-D	0.3522	0.2460	27.418	20.13	12/14/15 9:37	12/17/15 9:33
8-H-1-E-25	8-H-1-E	0.3532	0.2467	29.052	21.24	12/14/15 9:39	12/17/15 9:37
8-L-3-A-25	8-L-3-A	0.3472	0.2425	26.733	19.43	12/14/15 9:42	12/17/15 9:39
8-L-3-B-25	8-L-3-B	0.3516	0.2456	27.281	19.84	12/14/15 9:43	12/17/15 9:41
8-L-3-C-25	8-L-3-C	0.3545	0.2476	26.098	18.95	12/14/15 9:45	12/17/15 9:42
8-L-3-D-25	8-L-3-D	0.3515	0.2455	26.408	19.19	12/14/15 9:46	12/17/15 9:44
8-L-3-E-25	8-L-3-E	0.3466	0.2421	26.710	19.35	12/14/15 9:47	12/17/15 9:46
8-H-3-A-25	8-H-3-A	0.3512	0.2453	27.612	20.22	12/14/15 9:49	12/17/15 9:48
8-H-3-B-25	8-H-3-B	0.3472	0.2425	28.078	20.62	12/14/15 9:50	12/17/15 9:50
8-H-3-C-25	8-H-3-C	0.3535	0.2469	27.229	19.96	12/14/15 9:51	12/17/15 9:53

Table B.3. (contd)

Sample ID No.	Simulant ID Used	Mass of Wet Resin Added (g)	Mass of Dry Resin Added (g)	Mass of Simulant Added (g)	Vol of Simulant Added (mL)	Resin Added Date/Time	Resin Removed Date/Time
8-H-3-D-25	8-H-3-D	0.3499	0.2444	27.359	20.06	12/14/15 9:53	12/17/15 9:56
8-H-3-E-25	8-H-3-E	0.3488	0.2436	26.813	19.61	12/14/15 9:54	12/17/15 9:58
8-L-5-A-25	8-L-5-A	0.3527	0.2463	27.129	19.45	12/14/15 9:55	12/17/15 10:02
8-L-5-A-25D	8-L-5-A	0.3531	0.2466	27.587	19.78	12/14/15 9:57	12/17/15 10:03
8-L-5-B-25	8-L-5-B	0.3491	0.2438	26.001	18.70	12/14/15 9:58	12/17/15 10:05
8-L-5-B-25D	8-L-5-B	0.3506	0.2449	27.324	19.65	12/14/15 10:00	12/17/15 10:07
8-L-5-C-25	8-L-5-C	0.3497	0.2442	27.136	19.48	12/14/15 10:01	12/17/15 10:09
8-L-5-C-25D	8-L-5-C	0.3486	0.2435	29.157	20.93	12/14/15 10:02	12/17/15 10:11
8-L-5-D-25	8-L-5-D	0.3479	0.2430	28.038	20.12	12/14/15 10:04	12/17/15 10:13
8-L-5-D-25D	8-L-5-D	0.3531	0.2466	31.609	22.69	12/14/15 10:05	12/17/15 10:15
8-L-5-E-25	8-L-5-E	0.3521	0.2459	28.458	20.34	12/14/15 10:07	12/17/15 10:18
8-L-5-E-25D	8-L-5-E	0.3527	0.2463	28.206	20.16	12/14/15 10:08	12/17/15 10:20
8-H-5-A-25	8-H-5-A	0.3427	0.2393	28.510	20.59	12/14/15 10:11	12/17/15 10:22
8-H-5-B-25	8-H-5-B	0.3469	0.2423	28.900	20.94	12/14/15 10:13	12/17/15 10:23
8-H-5-C-25	8-H-5-C	0.3489	0.2437	28.559	20.67	12/14/15 10:15	12/17/15 10:25
8-H-5-D-25	8-H-5-D	0.3506	0.2449	30.472	22.03	12/14/15 10:18	12/17/15 10:27
8-H-5-E-25	8-H-5-E	0.3491	0.2438	31.937	23.06	12/14/15 10:20	12/17/15 10:31
8-L-6-A-25	8-L-6-A	0.3482	0.2432	31.646	22.57	12/14/15 10:23	12/17/15 10:33
8-L-6-B-25	8-L-6-B	0.3498	0.2443	31.686	22.62	12/14/15 10:25	12/17/15 10:35
8-L-6-C-25	8-L-6-C	0.3486	0.2435	31.593	22.54	12/14/15 10:26	12/17/15 10:36
8-L-6-D-25	8-L-6-D	0.3521	0.2459	31.793	22.67	12/14/15 10:28	12/17/15 10:38
8-L-6-E-25	8-L-6-E	0.3487	0.2435	32.125	22.79	12/14/15 10:29	12/17/15 10:40
8-H-6-A-25	8-H-6-A	0.3500	0.2444	31.438	22.64	12/14/15 10:31	12/17/15 10:42
8-H-6-A-25D	8-H-6-A	0.3492	0.2439	31.486	22.68	12/14/15 10:32	12/17/15 10:44
8-H-6-B-25	8-H-6-B	0.3540	0.2472	31.745	22.90	12/14/15 10:33	12/17/15 10:45
8-H-6-B-25D	8-H-6-B	0.3500	0.2444	31.778	22.92	12/14/15 10:38	12/17/15 10:47
8-H-6-C-25	8-H-6-C	0.3558	0.2485	31.725	22.86	12/14/15 10:39	12/17/15 10:50
8-H-6-C-25D	8-H-6-C	0.3508	0.2450	31.621	22.79	12/14/15 10:41	12/17/15 10:52
8-H-6-D-25	8-H-6-D	0.3444	0.2405	31.252	22.49	12/14/15 10:42	12/17/15 10:54
8-H-6-D-25D	8-H-6-D	0.3563	0.2488	31.373	22.58	12/14/15 10:43	12/17/15 10:56
8-H-6-E-25	8-H-6-E	0.3534	0.2468	31.135	22.32	12/14/15 10:45	12/17/15 10:58
8-H-6-E-25D	8-H-6-E	0.3431	0.2396	31.167	22.34	12/14/15 10:47	12/17/15 11:00

The batch contact temperature profiles for the 72-hour contact duration are shown in Figure B.1 and Figure B.2. The temperature fluctuation at the beginning and ending of the run is associated with intermittent opening and closing of the shaker table/incubator as samples in the set are individually loaded and unloaded. The opening and closing of the lid caused air exchange and concomitant cooling.

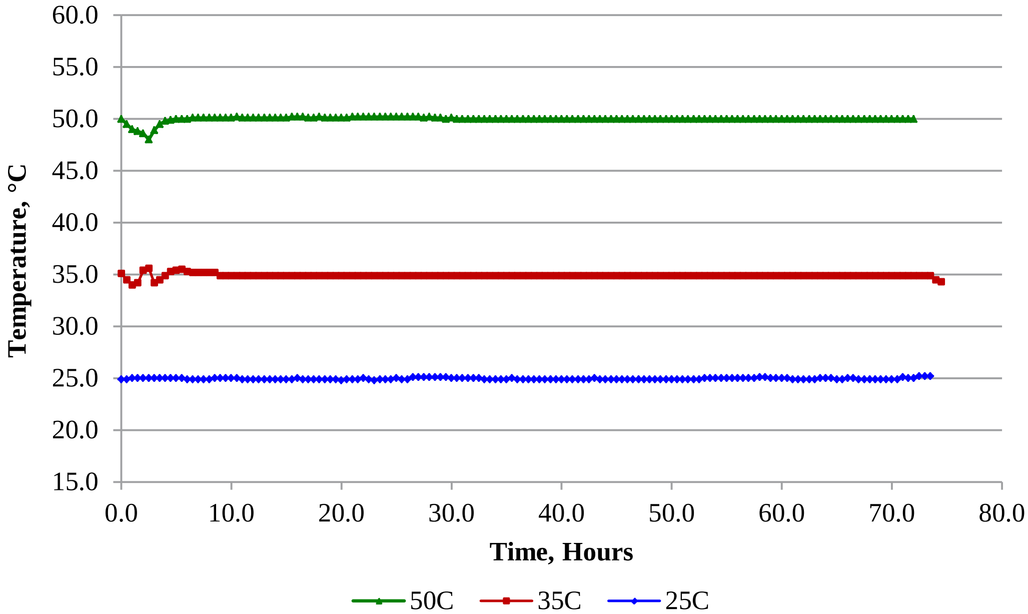

Figure B.1. Temperature Profiles for the First Sets of Batch Contact Samples

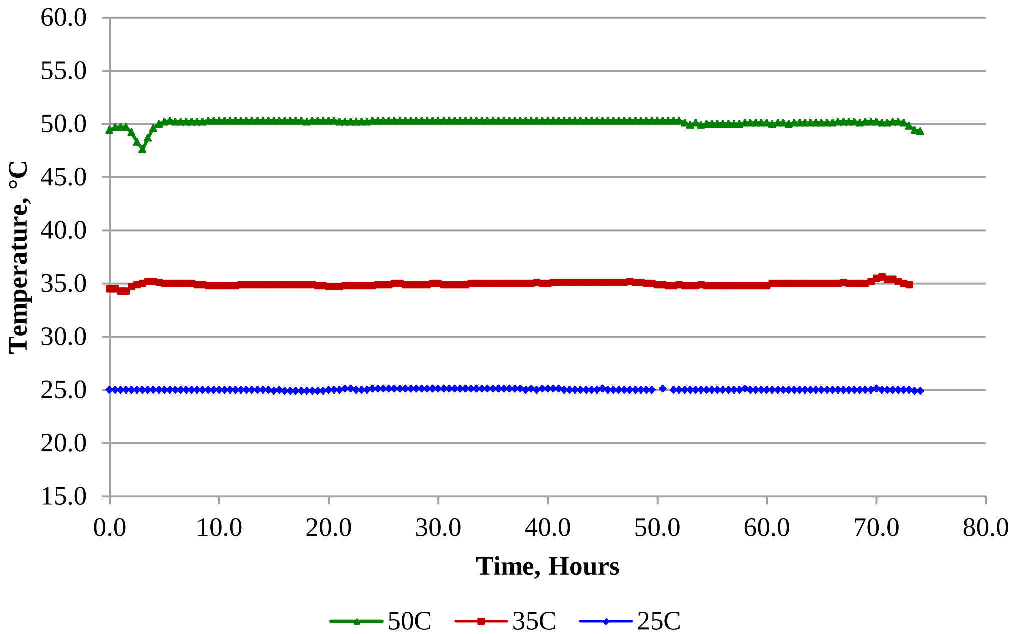

Figure B.2. Temperature Profiles for the Second Sets of Batch Contact Samples

Appendix C

Analytical Data

Appendix C

Analytical Data

Table C.1. Initial Simulant Analytical Data

Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH- (M)	Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH- (M)
5-H-2-A	0.670	234	113500	1.010	6-L-5-E	6620	14800	162000	0.099
5-H-2-B	6.46	220	111000	0.990	6-L-6-A	0.629	20000	152000	0.098
5-H-2-C	64.9	221	112000	0.995	6-L-6-B	6.36	19600	149000	0.101
5-H-2-D	659	228	113000	1.000	6-L-6-C	64.6	19500	149000	0.099
5-H-4-A	0.657	1880	113000	1.010	6-L-6-D	639	20000	151000	0.098
5-H-4-B	6.50	1870	112000	1.020	6-L-6-E	6470	19500	151000	0.098
5-H-4-C	62.4	1860	111000	1.010	8-H-1-A	0.689	23.1	181000	1.020
5-H-4-D	646	1890	112000	1.000	8-H-1-B	6.45	21.9	182000	0.965
5-H-5-A	0.660	13300	113000	1.010	8-H-1-C	64.3	25.3	184000	0.970
5-H-5-B	6.52	13100	112000	1.010	8-H-1-D	658	24.1	184000	0.950
5-H-5-C	64.6	13300	113000	1.000	8-H-1-E	6500	24.6	183000	0.965
5-H-5-D	658	13800	117000	1.010	8-H-3-A	0.663	1400	188000	1.020
6-H-1-A	0.656	22.8	145000	0.995	8-H-3-B	6.36	1360	182000	1.000
6-H-1-B	6.53	22.7	146000	0.990	8-H-3-C	63.3	1380	186000	1.010
6-H-1-C	65.0	24.3	145000	0.990	8-H-3-D	670	1360	182500	1.010
6-H-1-D	662	22.8	147000	0.995	8-H-3-E	6550	1380	184000	1.010
6-H-1-E	6440	22.9	143000	0.995	8-H-5-A	0.944	13600	184000	1.020
6-H-3-A	0.700	1360	146000	1.010	8-H-5-B	6.70	13500	184000	1.020
6-H-3-B	6.36	1310	144000	1.010	8-H-5-C	64.3	13300	183000	1.030
6-H-3-C	64.4	1350	146000	1.000	8-H-5-D	668	13400	182000	1.010
6-H-3-D	643	1345	147000	1.020	8-H-5-E	6450	13400	182000	1.000
6-H-3-E	6300	1270	139000	0.995	8-H-6-A	0.628	19100	181000	1.000
6-H-5-A	0.628	12900	143000	1.010	8-H-6-B	6.28	19200	180000	1.000
6-H-5-B	6.55	12700	142000	0.995	8-H-6-C	64.5	19200	181000	1.000
6-H-5-C	64.0	13200	145000	0.995	8-H-6-D	678	19400	183000	1.000
6-H-5-D	644	12900	143000	1.020	8-H-6-E	6480	19200	181000	1.000
6-H-5-E	6330	13300	147000	1.030	8-L-1-A	0.659	12.8	181000	0.098
6-H-6-A	0.637	18600	142000	1.010	8-L-1-B	6.48	11.8	178000	0.097
6-H-6-B	6.37	18100	139000	0.995	8-L-1-C	65.1	13.1	181000	0.097
6-H-6-C	62.3	18200	141000	0.995	8-L-1-D	578	12.8	182000	0.098
6-H-6-D	639	18600	143000	0.995	8-L-1-E	6350	12.1	180000	0.097
6-H-6-E	6240	18600	142000	1.010	8-L-3-A	0.707	1320	180000	0.098
6-L-1-A	0.687	12.1	144000	0.099	8-L-3-B	6.63	1320	177000	0.095
6-L-1-B	6.56	12.4	143000	0.098	8-L-3-C	64.8	1350	183000	0.096
6-L-1-C	65.5	11.4	143000	0.099	8-L-3-D	665	1325	178500	0.100
6-L-1-D	643	11.9	144000	0.102	8-L-3-E	6500	1300	178000	0.096
6-L-1-E	6280	12.1	152000	0.102	8-L-5-A	0.672	12700	171000	0.097
6-L-3-A	0.922	1280	144000	0.100	8-L-5-B	5.97	13500	180000	0.095
6-L-3-B	6.44	1270	143000	0.100	8-L-5-C	64.2	13200	178000	0.096

Table C.1. (contd)

Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH- (M)	Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH- (M)
6-L-3-C	62.9	1280	142000	0.099	8-L-5-D	673	13600	183000	0.099
6-L-3-D	681	1370	149500	0.101	8-L-5-E	6520	13500	182000	0.096
6-L-3-E	6660	1380	152000	0.100	8-L-6-A	0.697	18500	173000	0.097
6-L-5-A	0.653	13600	150000	0.098	8-L-6-B	6.30	18800	180000	0.096
6-L-5-B	6.83	13400	148000	0.097	8-L-6-C	63.1	19700	184000	0.095
6-L-5-C	64.9	13700	149000	0.099	8-L-6-D	662	19400	184000	0.098
6-L-5-D	662	13500	148000	0.098	8-L-6-E	6410	19500	183000	0.096

Table C.2. 50 °C Equilibrium Batch Contact Test Analytical Data

Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH^- (M)	Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH^- (M)
5-H-2-A-50	0.0366	240	116500	NM	6-L-5-E-50	5350	13100	145000	NM
5-H-2-B-50	0.555	229	113000	NM	6-L-6-A-50	0.168	18100	142000	NM
5-H-2-C-50	10.8	227	110000	NM	6-L-6-B-50	1.93	18500	142000	NM
5-H-2-D-50	260	224	110000	NM	6-L-6-C-50	23.8	18300	142000	NM
5-H-4-A-50	0.0659	1840	112000	NM	6-L-6-D-50	368	18800	143000	NM
5-H-4-B-50	0.849	1920	117000	NM	6-L-6-E-50	5200	18800	145000	NM
5-H-4-C-50	13.1	1830	111000	NM	8-H-1-A-50	0.0521	22.8	177000	NM
5-H-4-D-50	280	1830	111000	NM	8-H-1-B-50	0.666	24.2	187000	NM
5-H-5-A-50	0.152	13000	111000	NM	8-H-1-C-50	14.3	21.3	183000	NM
5-H-5-B-50	1.65	12800	109000	0.929	8-H-1-D-50	315	21.2	180000	NM
5-H-5-C-50	20.1	12700	110000	NM	8-H-1-E-50	5050	23.1	181000	NM
5-H-5-D-50	336	13200	113000	NM	8-H-3-A-50	0.0825	1320	183000	NM
6-H-1-A-50	0.0428	19.8	147000	NM	8-H-3-B-50	0.943	1280	178000	NM
6-H-1-B-50	0.659	19.8	144000	NM	8-H-3-C-50	16.4	1270	181000	NM
6-H-1-C-50	13.4	19.5	148000	NM	8-H-3-D-50	324	1320	182000	NM
6-H-1-D-50	314	20.4	144000	NM	8-H-3-E-50	5220	1325	177000	NM
6-H-1-E-50	5230	18.6	143000	NM	8-H-5-A-50	0.249	13100	177000	NM
6-H-3-A-50	0.0858	1310	145000	NM	8-H-5-B-50	1.87	12800	173000	NM
6-H-3-A-50D	0.0837	1310	146000	NM	8-H-5-C-50	24.2	13300	178000	NM
6-H-3-B-50	0.945	1280	142500	NM	8-H-5-D-50	377	13100	180000	0.904
6-H-3-B-50D	0.979	1360	142000	NM	8-H-5-E-50	5610	13000	176000	NM
6-H-3-C-50	16.3	1240	140000	NM	8-H-6-A-50	0.202	18900	178000	NM
6-H-3-C-50D	15.2	1210	143000	NM	8-H-6-A-50D	0.191	19000	179000	NM
6-H-3-D-50	312	1230	143000	NM	8-H-6-B-50	2.16	18600	176000	NM
6-H-3-D-50D	322	1370	145000	NM	8-H-6-B-50D	1.96	18700	176000	NM
6-H-3-E-50	5190	1390	146000	NM	8-H-6-C-50	25.5	19000	177000	NM
6-H-3-E-50D	5140	1310	144000	NM	8-H-6-C-50D	25.9	19100	180000	NM
6-H-5-A-50	0.209	13000	146000	NM	8-H-6-D-50	363	19100	179000	NM
6-H-5-B-50	1.81	12900	144000	NM	8-H-6-D-50D	376	18600	174000	NM
6-H-5-C-50	23.2	12700	145000	NM	8-H-6-E-50	5370	19100	180000	NM
6-H-5-D-50	372	12800	143000	NM	8-H-6-E-50D	5340	18700	174000	NM
6-H-5-E-50	5290	13200	146000	NM	8-L-1-A-50	0.0738	11.8	180000	NM
6-H-6-A-50	0.165	18900	150000	0.924	8-L-1-B-50	0.983	12.1	180000	NM
6-H-6-B-50	0.983	18600	141000	NM	8-L-1-C-50	18.0	12.9	180000	NM
6-H-6-C-50	18.0	18700	145000	NM	8-L-1-D-50	324	12.4	186000	NM
6-H-6-D-50	343	18900	150000	NM	8-L-1-E-50	5280	11.4	184000	NM
6-H-6-E-50	5200	19300	147000	NM	8-L-3-A-50	0.102	1280	175000	NM
6-L-1-A-50	0.0736	11.3	144000	NM	8-L-3-B-50	1.19	1250	172000	NM
6-L-1-A-50D	0.0512	<10.0	142000	NM	8-L-3-C-50	20.7	1270	174000	NM
6-L-1-B-50	0.676	11.2	142000	NM	8-L-3-D-50	367	1300	178000	NM
6-L-1-B-50D	0.659	10.4	142000	NM	8-L-3-E-50	5560	1300	178000	NM

Table C.2. (contd)

Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH^- (M)	Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH^- (M)
6-L-1-C-50	14.9	10.7	149000	0.0476	8-L-5-A-50	0.178	12900	175000	NM
6-L-1-C-50D	15.0	10.5	142000	NM	8-L-5-A-50D	0.176	12900	174000	NM
6-L-1-D-50	346	10.2	144000	NM	8-L-5-B-50	1.73	12700	173000	NM
6-L-1-D-50D	350	10.4	140000	NM	8-L-5-B-50D	1.73	13200	180000	NM
6-L-1-E-50	5220	11.1	142500	NM	8-L-5-C-50	25.5	12800	177000	NM
6-L-1-E-50D	5170	<10.0	143000	NM	8-L-5-C-50D	24.9	12900	176000	NM
6-L-3-A-50	0.110	1270	144000	NM	8-L-5-D-50	395	12900	174000	NM
6-L-3-B-50	0.984	1270	144000	NM	8-L-5-D-50D	382	12800	173000	NM
6-L-3-C-50	15.9	1290	144000	NM	8-L-5-E-50	5160	12800	173000	NM
6-L-3-D-50	356	1270	144000	NM	8-L-5-E-50D	5140	13000	177000	NM
6-L-3-E-50	5200	1290	145000	NM	8-L-6-A-50	0.218	18500	177000	NM
6-L-5-A-50	0.159	12900	143000	NM	8-L-6-B-50	2.03	18400	176000	NM
6-L-5-B-50	1.68	12600	141000	NM	8-L-6-C-50	26.8	18300	175000	NM
6-L-5-C-50	22.6	12700	142000	NM	8-L-6-D-50	395	18700	178000	NM
6-L-5-D-50	377	13100	144000	NM	8-L-6-E-50	5220	18100	171000	NM

Table C.3. 35 °C Equilibrium Batch Contact Test Analytical Data

Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH^- (M)	Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH^- (M)
5-H-2-A-35	0.0149	226	116000	NM	6-L-5-E-35	5090	12900	142000	NM
5-H-2-B-35	0.218	208	113500	NM	6-L-6-A-35	0.0995	18800	144000	NM
5-H-2-C-35	4.87	214	115000	NM	6-L-6-B-35	1.23	18300	143000	NM
5-H-2-D-35	174	207	114000	NM	6-L-6-C-35	17.5	18300	142000	NM
5-H-4-A-35	0.0275	1770	114000	NM	6-L-6-D-35	307	19100	147000	NM
5-H-4-B-35	0.391	1800	113000	NM	6-L-6-E-35	5100	18400	141000	NM
5-H-4-C-35	7.28	1750	115000	NM	8-H-1-A-35	0.0241	19.3	175000	NM
5-H-4-D-35	193	1720	114000	NM	8-H-1-B-35	0.421	19.6	171000	NM
5-H-5-A-35	0.0810	13400	116000	NM	8-H-1-C-35	9.51	20.0	173000	NM
5-H-5-B-35	0.953	12900	113000	NM	8-H-1-D-35	274	18.8	174000	NM
5-H-5-C-35	12.9	13100	114000	NM	8-H-1-E-35	4840	20.0	173000	NM
5-H-5-D-35	258	13200	114000	NM	8-H-3-A-35	0.0513	1260	175000	NM
6-H-1-A-35	0.0217	20.5	148000	NM	8-H-3-B-35	0.661	1260	174000	NM
6-H-1-B-35	0.344	19.1	147000	NM	8-H-3-C-35	11.4	1290	174000	NM
6-H-1-C-35	7.85	21.4	148000	NM	8-H-3-D-35	269	1270	172000	NM
6-H-1-D-35	228	19.0	147000	NM	8-H-3-E-35	4930	1290	174000	NM
6-H-1-E-35	4890	20.2	149000	NM	8-H-5-A-35	0.178	12900	180000	NM
6-H-3-A-35	0.0524	1240	150000	NM	8-H-5-B-35	1.38	12400	172500	NM
6-H-3-A-35D	0.0465	1270	147000	NM	8-H-5-C-35	17.6	12500	174000	NM
6-H-3-B-35	0.539	1280	148000	NM	8-H-5-D-35	291	12600	173000	NM
6-H-3-B-35D	0.585	1290	150000	NM	8-H-5-E-35	4960	12500	173000	NM
6-H-3-C-35	9.83	1280	141000	NM	8-H-6-A-35	0.130	18100	176000	NM
6-H-3-C-35D	10.03	1310	144000	NM	8-H-6-A-35D	0.134	18000	174000	NM
6-H-3-D-35	236	1280	141000	NM	8-H-6-B-35	1.54	17700	174000	NM
6-H-3-D-35D	244	1300	143000	NM	8-H-6-B-35D	1.52	17900	173000	NM
6-H-3-E-35	4920	1290	140000	NM	8-H-6-C-35	20.0	17900	174000	NM
6-H-3-E-35D	4770	1350	142000	NM	8-H-6-C-35D	20.7	17700	173000	NM
6-H-5-A-35	0.104	12300	138000	NM	8-H-6-D-35	327	17800	172000	NM
6-H-5-B-35	1.09	12600	139000	NM	8-H-6-D-35D	332	18000	174000	NM
6-H-5-C-35	17.3	12800	139000	NM	8-H-6-E-35	4880	18200	174000	NM
6-H-5-D-35	301	12600	139000	NM	8-H-6-E-35D	4870	18000	174000	NM
6-H-5-E-35	4670	12200	140000	0.914	8-L-1-A-35	0.0466	<10	176000	NM
6-H-6-A-35	0.113	18500	143500	NM	8-L-1-B-35	0.540	10.2	170000	NM
6-H-6-B-35	1.43	17500	141000	NM	8-L-1-C-35	12.2	<10	172000	NM
6-H-6-C-35	18.7	18200	143000	NM	8-L-1-D-35	266	<10	174000	NM
6-H-6-D-35	307	18800	144000	NM	8-L-1-E-35	4900	<10	172000	NM
6-H-6-E-35	4880	18700	145000	NM	8-L-3-A-35	0.0784	1230	171000	NM
6-L-1-A-35	0.0164	<10	140000	NM	8-L-3-B-35	0.745	1245	174000	NM
6-L-1-A-35D	0.0175	<10	146000	NM	8-L-3-C-35	14.3	1250	174000	0.0324
6-L-1-B-35	0.331	<10	142000	NM	8-L-3-D-35	315	1260	177000	NM
6-L-1-B-35D	0.323	<10	140000	NM	8-L-3-E-35	5130	1260	175000	NM

Table C.3. (contd)

Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH^- (M)	Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH^- (M)
6-L-1-C-35	8.68	<10	138000	NM	8-L-5-A-35	0.126	13000	176000	NM
6-L-1-C-35D	7.98	<10	142000	NM	8-L-5-A-35D	0.125	12900	176000	NM
6-L-1-D-35	246	<10	142000	NM	8-L-5-B-35	1.22	12600	174000	NM
6-L-1-D-35D	242	<10	142000	NM	8-L-5-B-35D	1.26	12800	174000	NM
6-L-1-E-35	4730	<10	144000	NM	8-L-5-C-35	21.1	13000	174000	NM
6-L-1-E-35D	4670	<10	141000	NM	8-L-5-C-35D	20.5	12500	173000	NM
6-L-3-A-35	0.0495	1255	145000	NM	8-L-5-D-35	339	12800	177000	NM
6-L-3-B-35	0.474	1240	134000	NM	8-L-5-D-35D	360	12400	175000	NM
6-L-3-C-35	9.23	1280	147000	NM	8-L-5-E-35	5110	12800	173000	NM
6-L-3-D-35	250	1240	138000	0.0323	8-L-5-E-35D	5000	12400	169000	NM
6-L-3-E-35	4730	1310	144000	NM	8-L-6-A-35	0.175	17400	174000	NM
6-L-5-A-35	0.0821	12900	144000	NM	8-L-6-B-35	1.55	18200	174000	NM
6-L-5-B-35	1.07	12900	144000	NM	8-L-6-C-35	20.2	18300	171000	NM
6-L-5-C-35	16.5	12900	143000	NM	8-L-6-D-35	355	17700	176000	NM
6-L-5-D-35	301	12800	144000	NM	8-L-6-E-35	5130	18500	176000	NM

Table C.4. 25 °C Equilibrium Batch Contact Test Analytical Data

Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH^- (M)	Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH^- (M)
5-H-2-A-25	0.0117	211	104000	0.929	6-L-5-E-25	4930	12800	149000	NM
5-H-2-B-25	0.204	198	103000	NM	6-L-6-A-25	0.0717	17900	149000	NM
5-H-2-C-25(1)	5.04	215	105000	NM	6-L-6-B-25	1.02	18300	144000	NM
5-H-2-D-25(1)	172	218	105000	NM	6-L-6-C-25	15.3	18200	149000	NM
5-H-4-A-25	0.0296	1730	104000	NM	6-L-6-D-25	297	18200	147000	NM
5-H-4-B-25	0.395	1720	104000	NM	6-L-6-E-25	5040	18300	148000	NM
5-H-4-C-25	6.56	1790	104000	NM	8-H-1-A-25	0.016	20.1	173000	NM
5-H-4-D-25	186	1800	105000	NM	8-H-1-B-25	0.207	20.5	175000	NM
5-H-5-A-25	0.0745	11900	103000	NM	8-H-1-C-25	6.80	18.3	175000	NM
5-H-5-B-25	0.853	12000	104000	NM	8-H-1-D-25	207	22.2	174000	NM
5-H-5-C-25	12.6	11800	104000	NM	8-H-1-E-25	4540	20.1	173000	NM
5-H-5-D-25	245	12000	105000	NM	8-H-3-A-25	0.036	1280	174000	NM
6-H-1-A-25	0.019	18.3	135000	NM	8-H-3-B-25	0.415	1280	175000	NM
6-H-1-B-25	0.295	17.9	135000	NM	8-H-3-C-25	7.80	1290	176000	NM
6-H-1-C-25	7.21	18.1	136000	NM	8-H-3-D-25	229	1280	176000	NM
6-H-1-D-25	219	19.9	139000	NM	8-H-3-E-25	4700	1260	171000	NM
6-H-1-E-25	4510	20.4	136000	NM	8-H-5-A-25	0.130	12900	175000	NM
6-H-3-A-25	0.0319	1240	139000	NM	8-H-5-B-25	0.924	12400	165000	NM
6-H-3-A-25D	0.040	1330	140000	NM	8-H-5-C-25	14.1	12500	170000	NM
6-H-3-B-25	0.556	1250	140000	NM	8-H-5-D-25	291	12200	163000	NM
6-H-3-B-25D	0.571	1280	140000	NM	8-H-5-E-25	4980	12200	175000	NM
6-H-3-C-25	9.43	1260	142000	NM	8-H-6-A-25	0.120	17700	169000	NM
6-H-3-C-25D	10.2	1320	142000	NM	8-H-6-A-25D	0.106	17700	172000	NM
6-H-3-D-25	233	1340	143000	NM	8-H-6-B-25	1.19	17750	169000	NM
6-H-3-D-25D	234	1240	140000	NM	8-H-6-B-25D	1.27	17800	171000	NM
6-H-3-E-25	4860	1300	143000	NM	8-H-6-C-25	17.5	18300	174000	NM
6-H-3-E-25D	4920	1330	141000	NM	8-H-6-C-25D	17.6	18200	174000	NM
6-H-5-A-25	0.111	12700	141000	NM	8-H-6-D-25	334	18400	176000	NM
6-H-5-B-25	1.18	12500	140000	NM	8-H-6-D-25D	322	18000	171000	NM
6-H-5-C-25	15.7	12700	141000	NM	8-H-6-E-25	5040	18700	175000	0.878
6-H-5-D-25	286	12800	140000	NM	8-H-6-E-25D	5070	18400	175000	NM
6-H-5-E-25	5010	12700	141000	NM	8-L-1-A-25	0.0245	10.9	175000	NM
6-H-6-A-25	0.103	18200	145000	NM	8-L-1-B-25	0.403	<10	171000	0.0320
6-H-6-B-25	1.15	17600	135000	NM	8-L-1-C-25	10.6	10.8	178000	NM
6-H-6-C-25	15.6	18300	148000	NM	8-L-1-D-25	242	11.4	179000	NM
6-H-6-D-25	286	18500	144000	NM	8-L-1-E-25	4830	<10	175000	NM
6-H-6-E-25	4680	18000	141000	NM	8-L-3-A-25	0.0383	1290	179000	NM
6-L-1-A-25	0.022	<10	144000	NM	8-L-3-B-25	0.474	1260	178000	NM
6-L-1-A-25D	0.027	<10	143000	NM	8-L-3-C-25	9.26	1240	177000	NM
6-L-1-B-25	0.296	<10	141000	NM	8-L-3-D-25	264	1260	177000	NM

Table C.4. (contd)

Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH^- (M)	Sample ID	Cs (mg/L)	K (mg/L)	Na (mg/L)	OH^- (M)
6-L-1-B-25D	0.298	10.5	144000	NM	8-L-3-E-25	4860	1300	178000	NM
6-L-1-C-25	8.36	10.3	141000	NM	8-L-5-A-25	0.0871	13000	180000	NM
6-L-1-C-25D	8.79	<10	144000	NM	8-L-5-A-25D	0.0787	13000	178000	NM
6-L-1-D-25	235.5	<10	148000	NM	8-L-5-B-25	0.817	12500	178000	NM
6-L-1-D-25D	228	<10	150000	NM	8-L-5-B-25D	0.877	12900	179000	NM
6-L-1-E-25	4670	<10	148000	NM	8-L-5-C-25	15.8	13000	178000	NM
6-L-1-E-25D	4820	<10	150000	NM	8-L-5-C-25D	16.1	12700	174000	NM
6-L-3-A-25	0.0398	1210	146000	NM	8-L-5-D-25	300	12900	176000	NM
6-L-3-B-25	0.438	1260	144000	NM	8-L-5-D-25D	325	12900	175000	NM
6-L-3-C-25	8.58	1310	147000	NM	8-L-5-E-25	5050	12700	177000	NM
6-L-3-D-25	257	1260	147000	NM	8-L-5-E-25D	5100	12800	176000	NM
6-L-3-E-25	4640	1280	144000	NM	8-L-6-A-25	0.132	18650	178500	NM
6-L-5-A-25	0.0630	12600	146000	NM	8-L-6-B-25	1.29	17800	172000	NM
6-L-5-B-25	0.892	12700	146000	NM	8-L-6-C-25	20.4	18500	176000	NM
6-L-5-C-25	16.0	13000	150000	NM	8-L-6-D-25	355	18800	182000	NM
6-L-5-D-25	286	12400	148000	NM	8-L-6-E-25	5360	18000	176000	NM

(1) Samples were reversed in the lab. Therefore, results were reversed in the table.

Appendix D

Isotherm Cs Loading Values

Appendix D

Isotherm Cs Loading Values

Table D.1. Cs Loading Results for 5 M Na, 0.005 M K, 1.0 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
5-H-2-A-50	2.75E-07	5.46E-04
5-H-2-B-50	4.18E-06	5.12E-03
5-H-2-C-50	8.13E-05	4.65E-02
5-H-2-D-50	1.96E-03	3.45E-01

Table D.2. Cs Loading Results for 5 M Na, 0.005 M K, 1.0 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
5-H-2-A-35	1.12E-07	4.74E-04
5-H-2-B-35	1.64E-06	4.50E-03
5-H-2-C-35	3.66E-05	4.22E-02
5-H-2-D-35	1.31E-03	3.45E-01

Table D.3. Cs Loading Results for 5 M Na, 0.005 M K, 1.0 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
5-H-2-A-25	8.80E-08	5.16E-04
5-H-2-B-25	1.53E-06	4.88E-03
5-H-2-C-25	3.78E-05	4.69E-02
5-H-2-D-25	1.29E-03	3.78E-01

Table D.4. Cs Loading Results for 5 M Na, 0.05 M K, 1.0 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
5-H-4-A-50	4.96E-07	4.99E-04
5-H-4-B-50	6.39E-06	4.88E-03
5-H-4-C-50	9.86E-05	4.27E-02
5-H-4-D-50	2.11E-03	3.13E-01

Table D.5. Cs Loading Results for 5 M Na, 0.05 M K, 1.0 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
5-H-4-A-35	2.07E-07	4.50E-04
5-H-4-B-35	2.94E-06	4.36E-03
5-H-4-C-35	5.48E-05	4.01E-02
5-H-4-D-35	1.45E-03	3.35E-01

Table D.6. Cs Loading Results for 5 M Na, 0.05 M K, 1.0 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
5-H-4-A-25	2.23E-07	4.84E-04
5-H-4-B-25	2.97E-06	4.72E-03
5-H-4-C-25	4.94E-05	4.21E-02
5-H-4-D-25	1.40E-03	3.58E-01

Table D.7. Cs Loading Results for 5 M Na, 0.35 M K, 1.0 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
5-H-5-A-50	1.14E-06	4.37E-04
5-H-5-B-50	1.24E-05	4.24E-03
5-H-5-C-50	1.51E-04	3.87E-02
5-H-5-D-50	2.53E-03	2.78E-01

Table D.8. Cs Loading Results for 5 M Na, 0.35 M K, 1.0 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
5-H-5-A-35	6.09E-07	4.11E-04
5-H-5-B-35	7.17E-06	4.11E-03
5-H-5-C-35	9.71E-05	3.71E-02
5-H-5-D-35	1.94E-03	2.88E-01

Table D.9. Cs Loading Results for 5 M Na, 0.35 M K, 1.0 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
5-H-5-A-25	5.61E-07	4.54E-04
5-H-5-B-25	6.42E-06	4.32E-03
5-H-5-C-25	9.48E-05	4.03E-02
5-H-5-D-25	1.84E-03	3.21E-01

Table D.10. Cs Loading Results for 6.5 M Na, 0 M K, 0.1 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-L-1-A-50	5.54E-07	5.13E-04
6-L-1-A-50D	3.85E-07	5.34E-04
6-L-1-B-50	5.09E-06	5.05E-03
6-L-1-B-50D	4.96E-06	5.07E-03
6-L-1-C-50	1.12E-04	4.31E-02
6-L-1-C-50D	1.13E-04	4.35E-02
6-L-1-D-50	2.60E-03	2.48E-01
6-L-1-D-50D	2.63E-03	2.52E-01
6-L-1-E-50	3.93E-02	9.16E-01
6-L-1-E-50D	3.89E-02	9.60E-01

Table D.11. Cs Loading Results for 6.5 M Na, 0 M K, 0.1 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-L-1-A-35	1.23E07	4.35E-04
6-L-1-A-35D	1.32E-07	4.65E-04
6-L-1-B-35	2.49E-06	4.43E-03
6-L-1-B-35D	2.43E-06	4.44E-03
6-L-1-C-35	6.53E-05	4.04E-02
6-L-1-C-35D	6.00E-05	4.03E-02
6-L-1-D-35	1.85E-03	2.85E-01
6-L-1-D-35D	1.82E-03	2.82E-01
6-L-1-E-35	3.56E-02	1.12E+00
6-L-1-E-35D	3.51E-02	1.17E+00

Table D.12. Cs Loading Results for 6.5 M Na, 0 M K, 0.1 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-L-1-A-25	1.67E-07	5.18E-04
6-L-1-A-25D	2.05E-07	5.21E-04
6-L-1-B-25	2.23E-06	4.81E-03
6-L-1-B-25D	2.24E-06	4.83E-03
6-L-1-C-25	6.29E-05	4.37E-02
6-L-1-C-25D	6.61E-05	4.33E-02
6-L-1-D-25	1.77E-03	3.16E-01
6-L-1-D-25D	1.72E-03	3.19E-01
6-L-1-E-25	3.51E-02	1.24E+00
6-L-1-E-25D	3.63E-02	1.13E+00

Table D.13. Cs Loading Results for 6.5 M Na, 0.035 M K, 0.1 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-L-3-A-50	8.28E-07	6.99E-04
6-L-3-B-50	7.40E-06	4.68E-03
6-L-3-C-50	1.20E-04	4.01E-02
6-L-3-D-50	2.68E-03	2.78E-01
6-L-3-E-50	3.91E-02	1.25E+00

Table D.14. Cs Loading Results for 6.5 M Na, 0.035 M K, 0.1 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-L-3-A-35	3.72E-07	6.28E-04
6-L-3-B-35	3.57E-06	4.28E-03
6-L-3-C-35	6.94E-05	3.77E-02
6-L-3-D-35	1.88E-03	3.04E-01
6-L-3-E-35	3.56E-02	1.19E+00

Table D.15. Cs Loading Results for 6.5 M Na, 0.035 M K, 0.1 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-L-3-A-25	2.99E-07	6.61E-04
6-L-3-B-25	3.30E-06	4.60E-03
6-L-3-C-25	6.46E-05	4.21E-02
6-L-3-D-25	1.93E-03	3.29E-01
6-L-3-E-25	3.49E-02	1.56E+00

Table D.16. Cs Loading Results for 6.5 M Na, 0.35 M K, 0.1 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-L-5-A-50	1.20E-06	4.19E-04
6-L-5-B-50	1.26E-05	4.39E-03
6-L-5-C-50	1.70E-04	3.56E-02
6-L-5-D-50	2.84E-03	2.46E-01
6-L-5-E-50	4.03E-02	1.07E+00

Table D.17. Cs Loading Results for 6.5 M Na, 0.35 M K, 0.1 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-L-5-A-35	6.18E-07	4.17E-04
6-L-5-B-35	8.05E-06	4.28E-03
6-L-5-C-35	1.24E-04	4.40E-02
6-L-5-D-35	2.26E-03	2.61E-01
6-L-5-E-35	3.83E-02	1.09E+00

Table D.18. Cs Loading Results for 6.5 M Na, 0.35 M K, 0.1 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-L-5-A-25	4.74E-07	4.46E-04
6-L-5-B-25	6.71E-06	4.57E-03
6-L-5-C-25	1.20E-04	3.76E-02
6-L-5-D-25	2.15E-03	2.87E-01
6-L-5-E-25	3.71E-02	1.32E+00

Table D.19. Cs Loading Results for 6.5 M Na, 0.50 M K, 0.1 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-L-6-A-50	1.26E-06	3.94E-04
6-L-6-B-50	1.45E-05	3.77E-03
6-L-6-C-50	1.79E-04	3.51E-02
6-L-6-D-50	2.77E-03	2.30E-01
6-L-6-E-50	3.91E-02	1.09E+00

Table D.20. Cs Loading Results for 6.5 M Na, 0.50 M K, 0.1 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-L-6-A-35	7.49E-07	3.88E-04
6-L-6-B-35	9.25E-06	3.72E-03
6-L-6-C-35	1.32E-04	3.43E-02
6-L-6-D-35	2.31E-03	2.44E-01
6-L-6-E-35	3.84E-02	1.00E+00

Table D.21. Cs Loading Results for 6.5 M Na, 0.50 M K, 0.1 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-L-6-A-25	5.39E-07	4.25E-04
6-L-6-B-25	7.67E-06	4.03E-03
6-L-6-C-25	1.15E-04	3.70E-02
6-L-6-D-25	2.23E-03	2.66E-01
6-L-6-E-25	3.79E-02	1.10E+00

Table D.22. Cs Loading Results for 6.5 M Na, 0 M K, 1.0 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-H-1-A-50	3.22E-07	5.29E-04
6-H-1-B-50	4.96E-06	5.11E-03
6-H-1-C-50	1.01E-04	4.42E-02
6-H-1-D-50	2.36E-03	2.97E-01
6-H-1-E-50	3.94E-02	1.05E+00

Table D.23. Cs Loading Results for 6.5 M Na, 0 M K, 1.0 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-H-1-A-35	1.63E-07	4.52E-04
6-H-1-B-35	2.59E-06	4.37E-03
6-H-1-C-35	5.91E-05	4.04E-02
6-H-1-D-35	1.72E-03	3.13E-01
6-H-1-E-35	3.68E-02	1.11E+00

Table D.24. Cs Loading Results for 6.5 M Na, 0 M K, 1.0 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-H-1-A-25	1.43E-07	4.86E-04
6-H-1-B-25	2.22E-06	4.83E-03
6-H-1-C-25	5.42E-05	4.48E-02
6-H-1-D-25	1.65E-03	3.39E-01
6-H-1-E-25	3.39E-02	1.50E+00

Table D.25. Cs Loading Results for 6.5 M Na, 0.035 M K, 1.0 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-H-3-A-50	6.46E-07	5.15E-04
6-H-3-A-50D	6.30E-07	5.21E-04
6-H-3-B-50	7.11E-06	4.60E-03
6-H-3-B-50D	7.37E-06	4.53E-03
6-H-3-C-50	1.23E-04	4.07E-02
6-H-3-C-50D	1.14E-04	4.00E-02
6-H-3-D-50	2.35E-03	2.80E-01
6-H-3-D-50D	2.42E-03	2.70E-01
6-H-3-E-50	3.91E-02	9.07E-01
6-H-3-E-50D	3.87E-02	9.63E-01

Table D.26. Cs Loading Results for 6.5 M Na, 0.035 M K, 1.0 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-H-3-A-35	3.94E-07	4.77E-04
6-H-3-A-35D	3.50E-07	4.66E-04
6-H-3-B-35	4.06E-06	4.25E-03
6-H-3-B-35D	4.40E-06	4.22E-03
6-H-3-C-35	7.40E-05	4.07E-02
6-H-3-C-35D	7.55E-05	4.03E-02
6-H-3-D-35	1.78E-03	2.97E-01
6-H-3-D-35D	1.84E-03	2.94E-01
6-H-3-E-35	3.70E-02	1.03E+00
6-H-3-E-35D	3.59E-02	1.15E+00

Table D.27. Cs Loading Results for 6.5 M Na, 0.035 M K, 1.0 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-H-3-A-25	2.40E-07	5.20E-04
6-H-3-A-25D	3.02E-07	5.08E-04
6-H-3-B-25	4.18E-06	4.49E-03
6-H-3-B-25D	4.30E-06	4.49E-03
6-H-3-C-25	7.10E-05	4.23E-02
6-H-3-C-25D	7.67E-05	4.18E-02
6-H-3-D-25	1.75E-03	3.14E-01
6-H-3-D-25D	1.76E-03	3.18E-01
6-H-3-E-25	3.66E-02	1.11E+00
6-H-3-E-25D	3.70E-02	1.08E+00

Table D.28. Cs Loading Results for 6.5 M Na, 0.35 M K, 1.0 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-H-5-A-50	1.57E-06	3.60E-04
6-H-5-B-50	1.36E-05	3.98E-03
6-H-5-C-50	1.75E-04	3.48E-02
6-H-5-D-50	2.80E-03	2.33E-01
6-H-5-E-50	3.98E-02	8.84E-01

Table D.29 Cs Loading Results for 6.5 M Na, 0.35 M K, 1.0 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-H-5-A-35	7.83E-07	3.81E-04
6-H-5-B-35	8.20E-06	3.92E-03
6-H-5-C-35	1.30E-04	3.36E-02
6-H-5-D-35	2.26E-03	2.51E-01
6-H-5-E-35	3.51E-02	1.21E+00

Table D.30. Cs Loading Results for 6.5 M Na, 0.35 M K, 1.0 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-H-5-A-25	8.35E-07	4.03E-04
6-H-5-B-25	8.88E-06	4.16E-03
6-H-5-C-25	1.18E-04	3.75E-02
6-H-5-D-25	2.15E-03	2.75E-01
6-H-5-E-25	3.77E-02	1.02E+00

Table D.31. Cs Loading Results for 6.5 M Na, 0.50 M K, 1.0 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-H-6-A-50	1.24E-06	3.25E-04
6-H-6-B-50	7.40E-06	3.79E-03
6-H-6-C-50	1.35E-04	3.10E-02
6-H-6-D-50	2.58E-03	2.06E-01
6-H-6-E-50	3.91E-02	7.23E-01

Table D.32. Cs Loading Results for 6.5 M Na, 0.50 M K, 1.0 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-H-6-A-35	8.46E-07	3.90E-04
6-H-6-B-35	1.08E-05	3.58E-03
6-H-6-C-35	1.41E-04	3.28E-02
6-H-6-D-35	2.31E-03	2.40E-01
6-H-6-E-35	3.67E-02	9.78E-01

Table D.33. Cs Loading Results for 6.5 M Na, 0.50 M K, 1.0 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
6-H-6-A-25	7.75E-07	3.96E-04
6-H-6-B-25	8.65E-06	3.85E-03
6-H-6-C-25	1.17E-04	3.40E-02
6-H-6-D-25	2.15E-03	2.58E-01
6-H-6-E-25	3.52E-02	1.15E+00

Table D.34. Cs Loading Results for 8 M Na, 0 M K, 0.1 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-L-1-A-50	5.55E-07	4.07E-04
8-L-1-B-50	7.40E-06	3.80E-03
8-L-1-C-50	1.35E-04	3.24E-02
8-L-1-D-50	2.44E-03	1.78E-01
8-L-1-E-50	3.97E-02	7.34E-01

Table D.35. Cs Loading Results for 8 M Na, 0 M K, 0.1 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-L-1-A-35	3.51E-07	4.41E-04
8-L-1-B-35	4.06E-06	4.25E-03
8-L-1-C-35	9.18E-05	3.86E-02
8-L-1-D-35	2.00E-03	2.21E-01
8-L-1-E-35	3.69E-02	1.05E+00

Table D.36. Cs Loading Results for 8 M Na, 0 M K, 0.1 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-L-1-A-25	1.84E-07	4.50E-04
8-L-1-B-25	3.03E-06	4.30E-03
8-L-1-C-25	7.98E-05	3.82E-02
8-L-1-D-25	1.82E-03	2.17E-01
8-L-1-E-25	3.63E-02	9.91E-01

Table D.37. Cs Loading Results for 8 M Na, 0.035 M K, 0.1 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-L-3-A-50	7.67E-07	3.97E-04
8-L-3-B-50	8.95E-06	3.77E-03
8-L-3-C-50	1.56E-04	3.04E-02
8-L-3-D-50	2.76E-03	2.03E-01
8-L-3-E-50	4.18E-02	6.56E-01

Table D.38. Cs Loading Results for 8 M Na, 0.035 M K, 0.1 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-L-3-A-35	5.90E-07	4.55E-04
8-L-3-B-35	5.61E-06	4.21E-03
8-L-3-C-35	1.08E-04	3.68E-02
8L-3-D-35	2.37E-03	2.54E-01
8-L-3-E-35	3.86E-02	1.00E+00

Table D.39. Cs Loading Results for 8 M Na, 0.035 M K, 0.1 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-L-3-A-25	2.88E-07	4.03E-04
8-L-3-B-25	3.57E-06	3.74E-03
8-L-3-C-25	6.97E-05	3.20E-02
8-L-3-D-25	1.99E-03	2.36E-01
8-L-3-E-25	3.66E-02	9.86E-01

Table D.40. Cs Loading Results for 8 M Na, 0.35 M K, 0.1 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-L-5-A-50	1.34E-06	3.38E-04
8-L-5-A-50D	1.32E-06	3.42E-04
8-L-5-B-50	1.30E-05	2.98E-03
8-L-5-B-50D	1.30E-05	2.92E-03
8-L-5-C-50	1.92E-04	2.69E-02
8-L-5-C-50D	1.87E-04	2.73E-02
8-L-5-D-50	2.97E-03	1.91E-01
8-L-5-D-50D	2.87E-03	2.01E-01
8-L-5-E-50	3.88E-02	9.37E-01
8-L-5-E-50D	3.87E-02	9.60E-01

Table D.41. Cs Loading Results for 8 M Na, 0.35 M K, 0.1 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-L-5-A-35	9.48E-07	3.90E-04
8-L-5-A-35D	9.41E-07	3.82E-04
8-L-5-B-35	9.18E-06	3.37E-03
8-L-5-B-35D	9.48E-06	3.33E-03
8-L-5-C-35	1.59E-04	3.06E-02
8-L-5-C-35D	1.54E-04	3.08E-02
8-L-5-D-35	2.55E-03	2.32E-01
8-L-5-D-35D	2.71E-03	2.21E-01
8-L-5-E-35	3.84E-02	9.87E-01
8-L-5-E-35D	3.76E-02	1.05E+00

Table D.42. Cs Loading Results for 8 M Na, 0.35 M K, 0.1 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-L-5-A-25	6.55E-07	3.48E-04
8-L-5-A-25D	5.92E-07	3.58E-04
8-L-5-B-25	6.15E-06	2.97E-03
8-L-5-B-25D	6.60E-06	3.07E-03
8-L-5-C-25	1.19E-04	2.90E-02
8-L-5-C-25D	1.21E-04	3.11E-02
8-L-5-D-25	2.26E-03	2.32E-01
8-L-5-D-25D	2.45E-03	2.41E-01
8-L-5-E-25	3.80E-02	9.15E-01
8-L-5-E-25D	3.84E-02	8.74E-01

Table D.43. Cs Loading Results for 8 M Na, 0.50 M K, 0.1 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-L-6-A-50	1.64E-06	3.31E-04
8-L-6-B-50	1.53E-05	2.94E-03
8-L-6-C-50	2.02E-04	2.53E-02
8-L-6-D-50	2.97E-03	1.84E-01
8-L-6-E-50	3.93E-02	8.18E-01

Table D.44. Cs Loading Results for 8 M Na, 0.50 M K, 0.1 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-L-6-A-35	1.32E-06	3.51E-04
8-L-6-B-35	1.17E-05	3.15E-03
8-L-6-C-35	1.52E-04	2.86E-02
8-L-6-D-35	2.67E-03	2.05E-01
8-L-6-E-35	3.86E-02	8.37E-01

Table D.45. Cs Loading Results for 8 M Na, 0.50 M K, 0.1 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-L-6-A-25	9.89E-07	3.95E-04
8-L-6-B-25	9.71E-06	3.49E-03
8-L-6-C-25	1.53E-04	2.97E-02
8-L-6-D-25	2.67E-03	2.13E-01
8-L-6-E-25	4.03E-02	7.39E-01

Table D.46. Cs Loading Results for 8 M Na, 0 M K, 1.0 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-H-1-A-50	3.92E-07	4.37E-04
8-H-1-B-50	5.01E-06	3.91E-03
8-H-1-C-50	1.08E-04	3.47E-02
8-H-1-D-50	2.37E-03	2.34E-01
8-H-1-E-50	3.80E-02	9.83E-01

Table D.47. Cs Loading Results for 8 M Na, 0 M K, 1.0 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-H-1-A-35	1.81E-07	4.79E-04
8-H-1-B-35	3.17E-06	4.40E-03
8-H-1-C-35	7.16E-05	4.00E-02
8-H-1-D-35	2.06E-03	2.78E-01
8-H-1-E-35	3.64E-02	1.19E+00

Table D.48. Cs Loading Results for 8 M Na, 0 M K, 1.0 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-H-1-A-25	1.19E-07	4.45E-04
8-H-1-B-25	1.56E-06	3.70E-03
8-H-1-C-25	5.12E-05	3.69E-02
8-H-1-D-25	1.56E-03	2.78E-01
8-H-1-E-25	3.42E-02	1.27E+00

Table D.49. Cs Loading Results for 8 M Na, 0.035 M K, 1.0 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-H-3-A-50	6.21E-07	4.05E-04
8-H-3-B-50	7.10E-06	3.70E-03
8-H-3-C-50	1.23E-04	3.24E-02
8-H-3-D-50	2.44E-03	2.44E-01
8-H-3-E-50	3.93E-02	9.08E-01

Table D.50. Cs Loading Results for 8 M Na, 0.035 M K, 1.0 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-H-3-A-35	3.86E-07	4.40E-04
8-H-3-B-35	4.97E-06	4.15E-03
8-H-3-C-35	8.58E-05	3.81E-02
8-H-3-D-35	2.02E-03	2.90E-01
8-H-3-E-35	3.71E-02	1.16E+00

Table D.51. Cs Loading Results for 8 M Na, 0.035 M K, 1.0 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-H-3-A-25	2.72E-07	3.89E-04
8-H-3-B-25	3.12E-06	3.80E-03
8-H-3-C-25	5.87E-05	3.38E-02
8-H-3-D-25	1.72E-03	2.72E-01
8-H-3-E-25	3.54E-02	1.12E+00

Table D.52. Cs Loading Results for 8 M Na, 0.35 M K, 1.0 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-H-5-A-50	1.87E-06	4.96E-04
8-H-5-B-50	1.41E-05	3.32E-03
8-H-5-C-50	1.82E-04	2.79E-02
8-H-5-D-50	2.84E-03	2.03E-01
8-H-5-E-50	4.22E-02	5.60E-01

Table D.53 Cs Loading Results for 8 M Na, 0.35 M K, 1.0 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-H-5-A-35	1.34E-06	5.17E-04
8-H-5-B-35	1.03E-05	3.54E-03
8-H-5-C-35	1.32E-04	3.21E-02
8-H-5-D-35	2.19E-03	2.54E-01
8-H-5-E-35	3.73E-02	1.01E+00

Table D.54. Cs Loading Results for 8 M Na, 0.35 M K, 1.0 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-H-5-A-25	9.78E-07	5.27-04
8-H-5-B-25	6.95E-06	3.76E-03
8-H-5-C-25	1.06E-04	3.20E-02
8-H-5-D-25	2.19E-03	2.55E-01
8-H-5-E-25	3.75E-02	1.05E+00

Table D.55. Cs Loading Results for 8 M Na, 0.50 M K, 1.0 M OH, 50 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-H-6-A-50	1.52E-06	2.90E-04
8-H-6-A-50D	1.44E-06	3.04E-04
8-H-6-B-50	1.63E-05	2.85E-03
8-H-6-B-50D	1.47E-05	2.88E-03
8-H-6-C-50	1.92E-04	2.69E-02
8-H-6-C-50D	1.95E-04	2.62E-02
8-H-6-D-50	2.73E-03	2.18E-01
8-H-6-D-50D	2.83E-03	2.05E-01
8-H-6-E-50	4.04E-02	7.41E-01
8-H-6-E-50D	4.02E-02	7.78E-01

Table D.56. Cs Loading Results for 8 M Na, 0.50 M K, 1.0 M OH, 35 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-H-6-A-35	9.78E-07	3.22E-04
8-H-6-A-35D	1.01E-06	3.24E-04
8-H-6-B-35	1.16E-05	3.30E-03
8-H-6-B-35D	1.14E-05	3.19E-03
8-H-6-C-35	1.50E-04	3.18E-02
8-H-6-C-35D	1.56E-04	3.10E-02
8-H-6-D-35	2.46E-03	2.40E-01
8-H-6-D-35D	2.50E-03	2.32E-01
8-H-6-E-35	3.67E-02	1.05E+00
8-H-6-E-35D	3.66E-02	1.05E+00

Table D.57. Cs Loading Results for 8 M Na, 0.50 M K, 1.0 M OH, 25 °C

Sample ID	Final Cs Concentration (M)	Cs Loading (mmol Cs/g resin)
8-H-6-A-25	9.03E-07	3.54E-04
8-H-6-A-25D	7.98E-07	3.65E-04
8-H-6-B-25	8.95E-06	3.55E-03
8-H-6-B-25D	9.56E-06	3.54E-03
8-H-6-C-25	1.32E-04	3.25E-02
8-H-6-C-25D	1.32E-04	3.28E-02
8-H-6-D-25	2.51E-03	2.42E-01
8-H-6-D-25D	2.42E-03	2.43E-01
8-H-6-E-25	3.79E-02	9.80E-01
8-H-6-E-25D	3.81E-02	9.89E-01

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