Phoenix Project

MECA Wet Chemistry Laboratory Calibration Report

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Phoenix Project

MECA Wet Chemistry Laboratory Calibration Report

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DOCUMENT CHANGE LOG

DATE	PAGES AFFECTED	REASON FOR CHANGE	VERSION/ REVISION
04/23/2008	All	First draft	Draft
05/05/2008	pg.40	Correction to conductivity calibration	Draft
05/27/2008	pg. 46-43	Correction to assignment of gain settings for Voltammetry	Draft
08/12/2008	pg. 33-34	Addition of perchlorate and calcium calibration	Draft
08/12/2008	pg. 17, 28	Correction to concentration of TS21 for flight solution	Draft
08/12/2008	pg. 31-32	Corrections to ISE slopes and intercepts (Cell 0 and 1)	Draft
08/14/2008	pg. 23-25	Addition of final temperature calibration using surface data.	Draft
11/17/2008	pg. 31-32	Corrections to ISE slopes and intercepts (Cell 2 and 3)	Draft
12/04/2008	pg. 17-18, 27- 28	Correction to concentration of TS21 flight solution due to hydration state of salts.	Draft
12/08/2008	pg. 38	Added pre-flight Thermo pH calibration for flight units (figure and table)	Draft
12/08/2008	pg. 24	Temperature calibration offsets due to heater state	Draft
12/08/2008	pg. 46	Correction to the CP electrode names for consistency.	Draft
12/08/2008	All	Complete document edit	Draft
3/11/2009	pg. 8,10, 15, 19 23, 25,27,38,43,69, 80	Spelling corrections and content clarification.	Draft
3/11/2009	pg. 15, 80	Updated tables	Draft

LIST OF TBD/TBRs

This document contains the following open items:

No.	Section	Item	Resp.	Due
1.	6	Pressure sensor offset	DeFlores/Kapit	TBD
2.	7	Temperature sensor offsets	DeFlores/Kapit	TBD
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1. Introduction

The purpose of this report is to document the calibration results for the Phoenix MECA Wet Chemistry Laboratory. Calibration is the process of acquiring the information necessary to convert measured digital data to scientifically meaningful quantities. This report also includes such quantities as actuator timing under various environmental conditions. Figure 1 and Table 1 identify the WCL cell positions and the actuator and beaker subassemblies for each cell position.

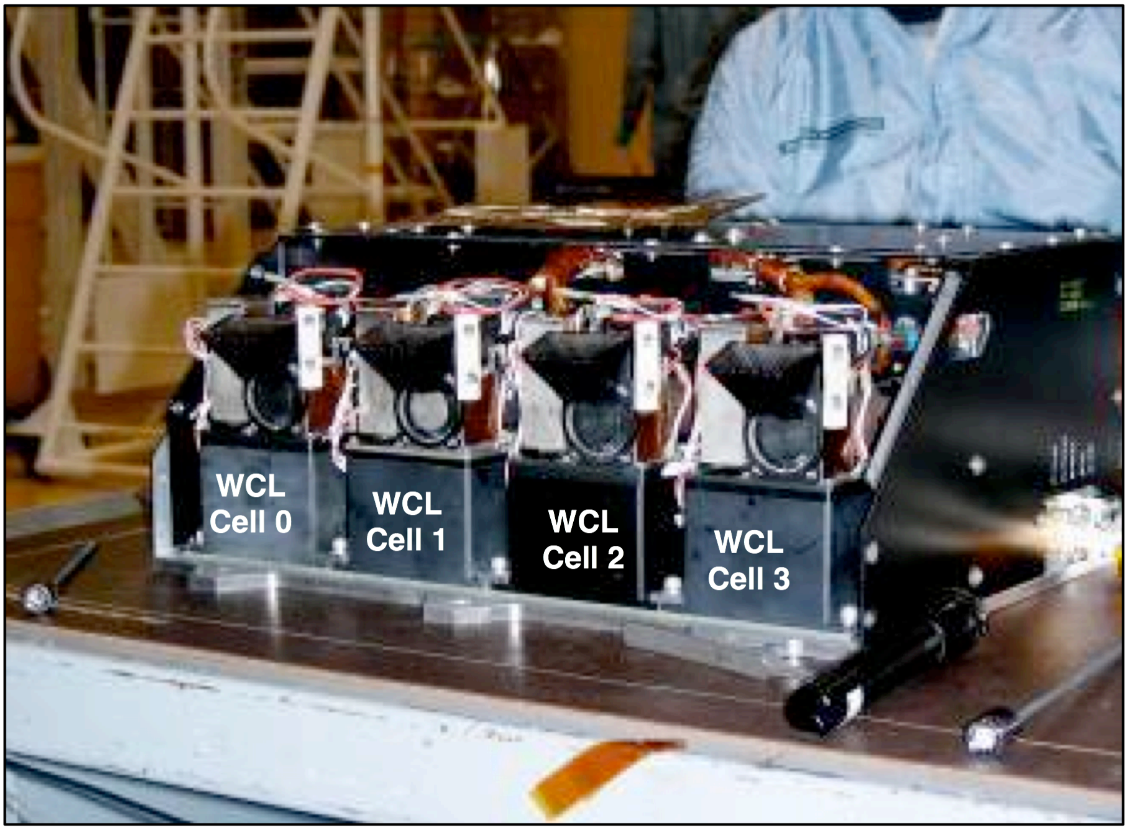


Figure 1. Photograph of MECA during ATLO at Lockheed-Martin just prior to integration onto the spacecraft. WCL Cell 0 is leftmost, near the OM sample entry. WCL cell 3 is right most, near the MECA external connectors.

Table 1. Actuator assembly, beaker serial number and crucible IDs for the WCL cell position. AA and beaker s/n documented in AIDS 248993. Crucible IDs documented in AIDS 248970, 248971, 248972, 248973 and 248982.

	Beaker 1	Beaker 2	Beaker 3	Beaker 4
	WCL CELL0	**WCL CELL1**	**WCL CELL2**	**WCL CELL3**
Actuator Assembly s/n	002	003	006	005
Beaker s/n	020	018	022	014
Crucible Flight Set #	***2***	***4***	***3***	***5***
Crucible 1 ID	F RS 0202 SC	F RS 0404 SC	F RS 0303 SC	F RS 0505 SC
Crucible 2 ID	F AN 0207 CS	F AN 0409 CS	F AN 0308 CS	F AN 0510 CS
Crucible 3 ID	F B1 0214 JS	F B1 0420 JS	F B1 0317 JS	F B1 0523 JS
Crucible 4 ID	F B2 0215 JS	F B2 0421 JS	F B2 0318 JS	F B2 0524 JS
Crucible 5 ID	F B3 0216 JS	F B3 0422 JS	F B3 0319 JS	F B1 0111 JS

2. Applicable Documents

The following documents are relevant to this report:

MECA Calibration, Characterization, and Cataloguing Plan; PHX-145-419, JPL D-34169

MECA Wet Chemistry Laboratory (WCL) Verification and Validation Test Report; PHX-565-145, JPL D-37142

3. Overview of Calibration Activities

Each WCL unit is comprised of one beaker and one actuator assembly (AA). Figure 2 identifies the beaker and the major AA components, including the tank, drawer, and reagent actuators, the pressure (P) sensor, tank temperature (T) sensor, drawer T sensor, and the thin-film heaters.

Each AA has three wax actuators, one each for opening/closing the sample drawer, deployment of the leaching solution from the tank, and deployment of the crucibles. Deployment time for each type of wax actuator was measured over the relevant temperature range.

Each AA has a pressure sensor to monitor the pressure inside the sealed WCL unit. The manufacturer calibrations of the P sensors were verified in the laboratory using external calibrated P sensors.

Each WCL has a temperature control system consisting of thin-film heaters and resistive temperature devices (RTDs) on the drawer and tank. The manufacturer calibrations of temperature were verified in the laboratory, and final T sensor calibration was performed using cruise T data in order to include cable and contact resistance because MECA was, out of schedule necessity, delivered in two parts.

In addition to a T sensor, each beaker has 23 chemical sensors mounted in its walls. Thermo Corporation (Thermo) provided the sensors. Chemical sensor calibrations basically consist of measuring voltage and current changes referenced to the known concentration of the chemical species of interest, using a calibrated analog board at controlled temperatures. The ion selective electrodes (ISEs), except for Br^-, I^-, and pH, were calibrated multiple times during the course of assembly using a series of five test solutions with known ion concentrations. The pH sensors were calibrated using air-saturated and 5% CO_2-saturated test solutions with pH values determined by external commercial pH sensors. Br^- and I^- sensors were calibrated only before integration into the beaker because addition of these ions will poison the Cl^- sensor. Calibration for voltage and current values to digital numbers for conductivity, chronopotentiometry and voltammetry were performed using simple circuits that properly model the electrical properties of the measurement using the flight analog board. (s/n 102).

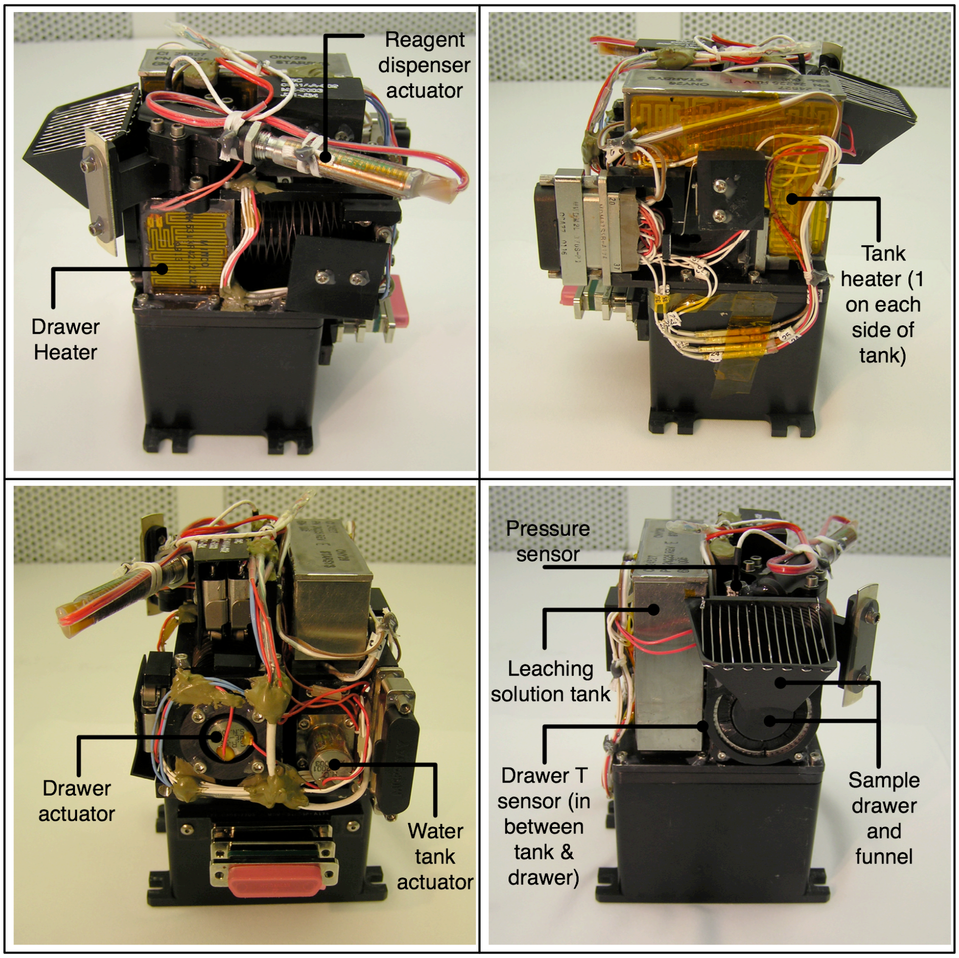


Figure 2. Photographs of each size of AA s/n 006 after integration with beaker s/n 022. Major components discussed in this report are labeled.

4. AA Actuation Times

Knowledge of actuation times over the temperature range relevant to landed operations is needed to help plan activities for a given sol as well as to protect the reagent dispenser actuator from over heating. Determination of an actuation time must be done under careful thermal simulation because the state of the various WCL heaters (beaker, drawer, and tank) can significantly impact the starting temperature of the various actuators (drawer open/close, tank deployment, and reagent dispenser). In particular, during WCL operations, the beaker heater and drawer heater will be energized to maintain the solution temperature at a set point between 0 and 20 ˚C. The starting temperature for the drawer and reagent dispenser actuators will depend upon the set points of these heaters as well as the external environment temperature.

To understand the relationship between beaker and drawer heater set points, the external environment temperature, and the actuator starting temperatures, a series of experiments were performed to determine the temperature of various positions on the WCL as a function of heater set points and chamber temperature. Flight-lot beaker s/n 021 was filled with 25 mL of leaching solution and integrated with EM AA s/n 001. The WCL unit was placed in a thermal-vacuum chamber on G11 shims and a MECA-like base plate to simulate the thermal environment of the WCL unit on the Phoenix deck. Thermocouples were used to monitor the temperature along various point of the WCL unit as the beaker and drawer T set points were varied (10, 20, 25, 30, 40 ˚C) as a function of chamber set point (0, -20, -40 ˚C) at ~70 torr pressure. [Note: because the EM AA does not seal, the chamber pressure had to be higher than the vapor pressure of water. 70 torr provided adequate pressure to avoid boiling 40 ˚C water.]

Figures 3–5 plot the results of the tests described above. These results will be used when starting temperatures for actuator timing are discussed in later sections. In general, the tank T sensor and RDA temperature linearly track the temperature set point of the beaker and drawer, which are always set to the same T point in this experiment.

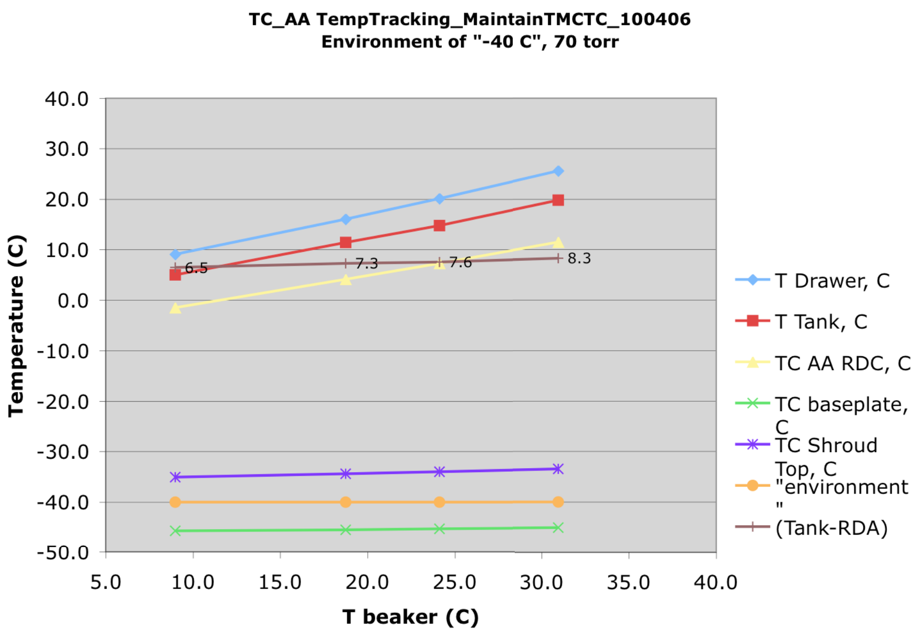


Figure 3. Tank and RDA temperatures as the beaker and drawer T set points are increased in a chamber environment of -40 ˚C and 70 torr. The RDA temperature is measured with a thermocouple. Tank, drawer, and beaker T sensors are measured through a WCL testbed.

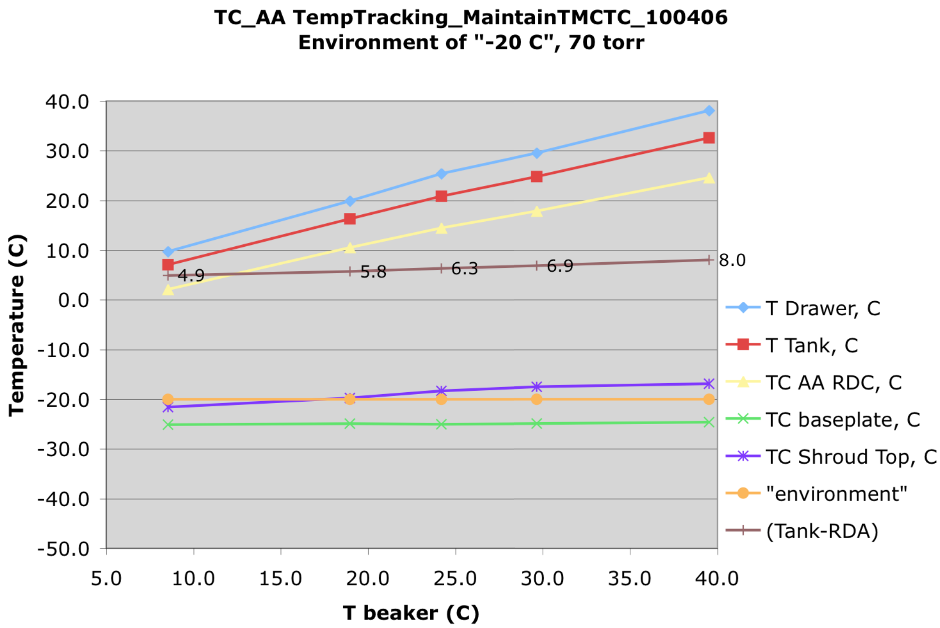


Figure 4. Tank and RDA temperatures as the beaker and drawer T set points are increased in a chamber environment of -20 ˚C and 70 torr. The RDA temperature is measured with a thermocouple. Tank, drawer, and beaker T sensors are measured through a WCL testbed.

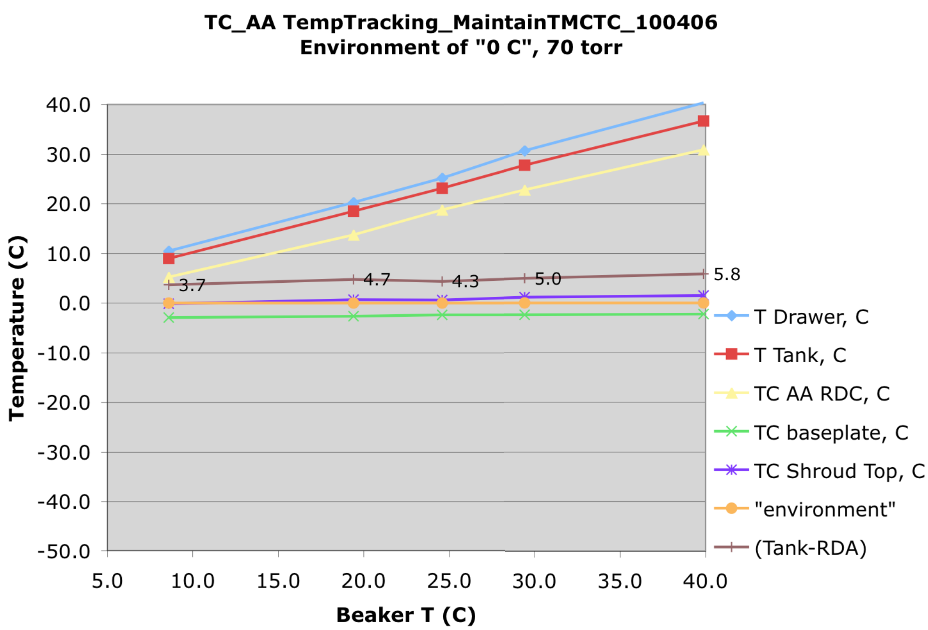


Figure 5. Tank and RDA temperatures as the beaker and drawer T set points are increased in a chamber environment of 0 ˚C and 70 torr. The RDA temperature is measured with a thermocouple. Tank, drawer, and beaker T sensors are measured through a WCL testbed.

4.1. Drawer Actuation

The AA provides an electronic signal indicating when the sample drawer reaches the fully extended or retracted positions. These limit switch signals are used to determine the time required for the drawer to fully extend or retract under several environmental conditions. The results are summarized in Table 2.

Table 2. Drawer actuation timing summary.

AA s/n	Chmbr T (˚C)	P (torr)	# of Trials	Average Full Extend Time hr:mm:ss	Standard Deviation	Average Full Retract Time hr:mm:ss	Standard Deviation	HW/SW	Comments
002	RM	RM	4	0:02:20	0:00:03	0:02:59	0:00:14	FM Testbed	no beaker
003	RM	RM	3	0:02:32	0:00:04	0:03:21	0:00:23	FM Testbed	no beaker
005	RM	RM	3	0:02:10	0:00:02	0:03:09	0:00:23	FM Testbed	no beaker
006	RM	RM	4	0:02:40	0:00:20	0:03:08	0:00:10	FM Testbed	no beaker only 2 trials for retraction
All above results			**0:02:26**	**0:00:15**	**0:00:13**	**0:03:08**	**0:00:18**		

Room temperature actuation times were determined for all AAs to verify in-family actuation time. Over 14 trials, the average full extension time at room T and P is 2 min 26 sec, with a standard deviation of 15 sec. The average full retraction time is 3 min 8 sec with a standard deviation of 18 sec.

The EM AA was used by Starsys to determine actuation under worse case environment conditions of -40 ˚C, 10 Torr, without any additional heating by other WCL components. Starsys was unable to warm the drawer beyond ~-30 ˚C using the drawer heater, likely because the thermal environment of the AA was not realistic. In addition to no other heater components being energized, it is not indicated if the beaker was a plastic or metal mockup. Full extension required 5 min 38 sec and full retraction required 12 min 31 minutes. Although the thermal conditions are far from flight-like, these results are included in this report as an upper limit under conditions much harsher than will be encountered during surface operations.

On the surface of Mars, drawer actuation will always be done with a drawer warmed > 0 ˚C. In addition to an energized drawer heater, either a tank heater (just prior to solution deployment) or a beaker heater (after solution deployment) will also be energized. For the later case, Figures 3–5 demonstrate that both the beaker T and drawer T can be controlled to the same set point (within 5 C even in -40 ˚C, 10 Torr environment) over the range of 5 to 40 ˚C. Thus, with the assumption that the temperature of the drawer actuator is the same as the drawer, the room T, P actuation times are representative of the actuation time expected during Mars operations.

4.2. Tank Deployment Actuation

The AA provides an electronic signal indicating when the tank deployment actuator reaches its fully extended position. This limit switch signal is used to measure the time required for the tank actuator to puncture the sealing disk and deploy the leaching solution into the beaker. The results are summarized in Table 3.

Deployment of the tank on Mars will only occur after the solution in the tank has been warmed to 5–25 ˚C by energizing the tank heaters. With the assumption that the tank deployment actuator will similarly be at a temperature of 5–25 ˚C, the room temperature actuation times in Table 3 are representative of the actuation times to be expected during Mars operations. An average tank deployment time of 1 min 27 sec was observed with a standard deviation of 3 sec.

Table 3. Tank Actuator Timing Summary

AA s/n	Chmbr T (˚C)	P (torr)	Tank Deployment Time hh:mm:ss	HW/SW	Comments
002	RM	66	0:01:30	FM Testbed	RT soln, open beaker AIDS 248394
003	RM	62	0:01:28	FM Testbed	RT soln, open beaker AIDS 248395
005	RM	60–70	0:01:24	FM Testbed	RT soln, open beaker AIDS 248396
006	RM	68	0:01:26	FM Testbed	RT soln, open beaker AIDS 248397
Average			**0:01:27**		
Standard Deviation			**0:00:03**		

4.3. Reagent Dispenser Actuation

The reagent dispenser actuator (RDA) was added to the MECA WCL 2001 heritage hardware with design constraints that did not permit the additional of an electronic signal mechanism to indicate when the dispenser had fully extended and dropped the crucible. Therefore, determination of the appropriate applied power duration time is necessary. Power must be applied for a duration long enough to dispense a crucible, but not so long as to overheat the wax actuator and potentially damage the crucible dispensing mechanism.

Starsys determined a margined time to dispense crucibles based on the starting temperature of the RDA (Starsys MECA Reagent Dispenser Applied Power Duration Curve Summary Report, 27308, dated March 14, 2006). They determined the applied power duration curve to be defined by the following 2nd order polynomial equation:

$$Y = 0.0165\ X2 - 3.15\ X + 242.14$$

Where Y = duration (sec) that 5.0 Vdc is applied to the 4.4 Ohm RDA heater

X= starting temperature (˚C) of the RDA

MECA does not provide information on the RDA starting temperature, but the data shown in Figures 3–5 show that the Tank T sensor output provides an understood proxy for the RDA temperature. The two temperatures track well with an average difference between the tank T sensor and the RDA temperature (as measured with an external thermocouple) of 6.1 ˚C over the range of conditions plotted in Figures 3–5. As shown in Table 4, we estimate that less than a 3.2% error in actuation time will occur if the RDA temperature is approximated in the FSW using the relationship

$$\text{RDA T (˚C)} = \text{Tank T (˚C)} - 6.077$$

Additional experiments were performed to demonstrate that all flight AAs had RDAs with in-family timing. Table 5 summarizes the results. Average room T and room P crucible drop times range from 2 min 16 sec to 3 min 11 sec, all acceptably within family. This data was obtained on un-integrated AAs, all of which had gone through re-work at JPL to remove excess lubrication and incorrectly installed o-rings within the mechanism.

Subsequent timing experiments were conducted after recognizing that the testbed electronics delivered a higher voltage to the RDA than the flight electronics. Experiments were conducting at the lowest expected voltage (4.0 Vdc) and with conditions that simulated surface operations. The EM AA 001 was integrated with a solution-filled flight-like beaker and placed into a thermal-vacuum chamber. The solution temperature and drawer temperatures were controlled at 5 ˚C, which is the temperature at which the reagent and acid crucibles will be added on Mars. The RDA temperature was -5 ˚C, consistent with the data presented in Figures 3–5. The chamber temperature was allowed to remain at room temperature, under the assumption that the RDA temperature, not the background chamber temperature, is the key parameter. Using 4.0 Vdc, we measured a drop time of 3 min 58 sec. The Starsys curve, based on 5.0 Vdc to heater, predicts a crucible drop time for this of 4 min 18 sec. One would expect a longer actuation time for the lower voltage, but it must be noted that JPL reworked all Starsys RDA actuators to correct the placement of an internal o-ring that impacted the actuator stroke length and produced shorter actuation times relative to the Starsys tests before delivery to JPL.

Subsequent experiments demonstrated that the RDA could be powered on the bench for up to 6 minutes without overheating with margin. Since all crucible drops will be into a warmed beaker with the RDA temperature greater than -5 ˚C, we concluded that all crucible drops could be performed with a fixed applied power duration of 5 minutes.

Table 4. Error analysis for tank T proxy for RDA applied power duration. The tank T can be used as a proxy for the RDA temperature.

Calculation	Units	Condition
6.08	°C	Average tank-RDA difference
-1.50	°C	Coldest RDA temp
30.9	°C	Hottest RDA temp
11.5	°C	RDA temp at farthest tank-RDA
5.27	°C	RDA temp at closest tank-RDA
-1.10	°C	FSW RDA coldest temp estimate
30.6	°C	FSW RDA hottest temp estimate
13.7	°C	FSW temp at farthest tank-RDA
2.90	°C	FSW temp at closest tank-RDA
246.9	Seconds	Actual required actuation time at coldest temp
160.6	Seconds	Actual required actuation time at hottest temp
208.1	Seconds	Actual required actuation time at farthest temp
226.0	Seconds	Actual required actuation time at closest temp
245.6	Seconds	Estimated required actuation time at coldest temp
161.2	Seconds	Estimated required actuation time at hottest temp
202.0	Seconds	Estimated required actuation time at farthest temp
233.2	Seconds	Estimated required actuation time at closest temp
-1.3	Seconds	Error in required actuation time at coldest temp
0.5	Seconds	Error in required actuation time at hottest temp
-6.1	Seconds	Error in required actuation time at farthest temp
7.2	Seconds	Error in required actuation time at closest temp
-0.51%	%	% error in required actuation time at coldest temp
0.33%	%	% error in required actuation time at hottest temp
-2.92%	%	% error in required actuation time at farthest temp
3.16%	%	% error in required actuation time at closest temp

Table 5. Reagent dispenser actuation timing summary. A fixed actuation time of 5 minutes will be used for all units.

AA s/n	T (˚C)	P (torr)	# of Trials	Average Crucible Drop Time hr:mm:ss	Min hr:mm:ss	Max hr:mm:ss	Standard Deviation hr:mm:ss	HW/SW	Comments
001	RM	RM	5	0:02:16	0:02:13	0:02:20	0:00:03	Testbed	AA Actuator times_rev5_Calreport.xls All tests post RDA rework
002	RM	RM	7	0:02:56	0:02:42	0:03:12	0:00:11	Testbed	AA Actuator times_rev5_Calreport.xls All tests post RDA rework
003	RM	RM	7	0:03:09	0:02:48	0:02:55	0:00:18	Testbed	AA Actuator times_rev5_Calreport.xls All tests post RDA rework
004	RM	RM	1	0:03:03	0:03:03	0:03:03	na	Testbed	AA Actuator times_rev5_Calreport.xls All tests post RDA rework
005	RM	RM	5	0:03:11	0:03:05	0:03:19	0:00:05	Testbed	AA Actuator times_rev5_Calreport.xls All tests post RDA rework
006	RM	RM	7	0:03:09	0:02:55	0:03:29	0:00:15	Testbed	AA Actuator times_rev5_Calreport.xls All tests post RDA rework
001	RM	RM	1	0:02:40	na	na	na	4.0 V @ RDA	AIDS 248968
001	RM	RM	1	0:01:47	na	na	na	4.8 V @ RDA	AIDS 248968
001	RM	7	1	0:03:58	na	na	na	4.0 V @ RDA +5 ˚C drawer -5 ˚C ± 1 ˚C RDA	AIDS 248968 Represents expected conditions (soln @ +5 ˚C, drawer @ +5 ˚C)
001	RM	7	1	0:02:23	na	na	na	4.8 V @ RDA +5 ˚C drawer -5 ˚C ± 1 ˚C RDA	AIDS 248968 Represents expected conditions (soln @ +5 ˚C, drawer @ +5 ˚C)

5. Crucible Reagents and Dissolution Time

The crucible identification numbers and content masses are identified in Table 6 and reagent preparation of the crucible is presented in Table 7.

This section discusses the preparation of the flight crucibles and dissolution times. The barium chloride ($BaCl_2$) addition was performed through a solid phase packing procedure developed at Tufts University. Table 6 presents the masses of the barium crucibles for the given flight set and crucible identification number.

Table 6. Mass of $BaCl_2$ crucibles (B) with lot number and ID for the WCL cells.

	Crucible Lot # and ID		Empty Crucible [g]	Filled Crucible [g]	$BaCl_2$ Mass [g]
CELL0	2	F B1 0214 JS	0.3157	0.4244	***0.1087***
		F B2 0215 JS	0.3107	0.4205	***0.1098***
		F B3 0216 JS	0.3163	0.4283	***0.1120***
CELL1	4	F B1 0420 JS	0.3209	0.4330	***0.1121***
		F B2 0421 JS	0.3187	0.4332	***0.1145***
		F B3 0422 JS	0.3143	0.4246	***0.1103***
CELL2	3	F B1 0317 JS	0.3170	0.4263	***0.1093***
		F B2 0318 JS	0.3095	0.4235	***0.1140***
		F B3 0319 JS	0.3197	0.4318	***0.1121***
CELL3	5	F B1 0523 JS	0.3186	0.4259	***0.1073***
		F B2 0524 JS	0.3110	0.4247	***0.1137***
		F B1 0111 JS	0.3139	0.4152	***0.1013***

The reagent and acid crucibles were prepared through volumetric addition of a concentrated solution to the flight crucibles.

The standards crucible (RN) contains six salt compounds that act as a second point for calibration of the beaker sensors. Table 7 reports the masses of the reagents; ammonium nitrate (NH_4NO_3), magnesium nitrate hexahydrate ($Mg(NO_3)_2 \cdot 6H_2O$), calcium chloride ($CaCl_2$), potassium chloride (KCl), and barium chloride ($BaCl_2$). The barium and calcium dihydrated salts were dried in an over with dryerite at 120°C +/- 10°C for a month. Each salt (1-5) is prepared in a 25 mL solution of nano-pure H_2O and sodium bicarbonate ($NaHCO_3$) is prepared in a 50 mL solution. 2 mL of reagents 1-5 and 4 mL of the $NaHCO_3$ solution are combined and volumetrically diluted to 100 mL in nano-pure H_2O. 30 μL of the total solution is added to each flight crucible and dried for 18 hours. The mass of the total contents is 0.5 mg.

The acid crucibles are prepared through the addition of 14 μL of a solution of 0.2001 g of 2-nitrobenzoic acid (NBA) in 0.7 mL of reagent grade methanol. Crucibles were dried for 1 hour at STP. This gives a mass of approximately 4 mg of dehydrated NBA per crucible.

Table 7. Reagents masses for preparation of standards and acid crucibles.

Reagent Addition Preparation

	Reagent	Mass [g]	Initial Solution
1	NH_4NO_3	2.0016	in 25 mL nano-pure H_2O
2	$Mg(NO_3)_2{\bullet}6H_2O$	6.6104	in 25 mL nano-pure H_2O
3	$CaCl_2$	3.6752	in 25 mL nano-pure H_2O
4	KCl	1.8642	in 25 mL nano-pure H_2O
5	$BaCl_2$	6.1076	in 25 mL nano-pure H_2O
6	$NaHCO_3$	2.1003	in 50 mL nano-pure H_2O

Acid Addition Preparation

	Reagent	Mass [g]	Initial Solution
	NBA	0.2001	in 0.7 mL Methanol

The time to dissolve the reagents from the crucibles after deployment into the leaching solution was measured experimentally by Tufts. The full report from Tufts may be found in Appendix B. The final concentration of the ionic species of the reagent crucible (M-TS21) is included in Table 15.

The dissolution experiments were conducted by dropping a filled crucible into 25 mL of leaching solution in a beaker at a controlled temperature. The dissolution of the salts in the calibrant crucible was monitored with commercial Cl^-, Ca^{2+}, and K+ ISE sensors. Dissolution of the 2-nitro-benzoic acid in the acid crucible was monitored with a commercial pH sensor. Dissolution of the $BaCl_2$ crucible was monitored with a Cl^- commercial ISE. In each case, full dissolution of the crucible contents was confirmed by comparing the final ISE reading with that obtained by mixing in the equivalent amount of reagent in a second beaker filled with 25 mL of leaching solution.

Table 8 summarizes the results of the Tufts dissolution experiments. The calibration and acid crucibles dissolve quickly in 5 ˚C leaching solution, but Tufts recommends increasing the beaker temperature to 20 ˚C in order to dissolve the $BaCl_2$ in "less than an hour".

Table 8. Summary of Crucible Dissolution Times

Crucible	Temperature of Leaching Solution	
	5 ˚C	25 ˚C
Calibrant (salts)	3 min	--
Acid (0.004 g 2-nitro-benzoic acid)	< 5 min	--
$BaCl_2$ (0.1 g)	~80 min	30–50 min

6. Actuator Assembly Pressure Sensors

The Kulite Pressure sensor located in the actuator assembly (AA) measured the internal pressure of the WCL pressure chamber during operation. For calibration, pressure sensors were not calibrated with the integrated beaker. The AA pressure sensor was continuously monitored over the range of 1.3-1000 mbar. Two external pressure sensors are also monitored; a Ferran-type gauge (1-100 torr) and an external conductance manometer (not-calibrated) for range 100-750 torr. Calibration measurement is repeated at temperatures ranging room temp to -40^{o}C to confirm temperature compensation (Figure 7).

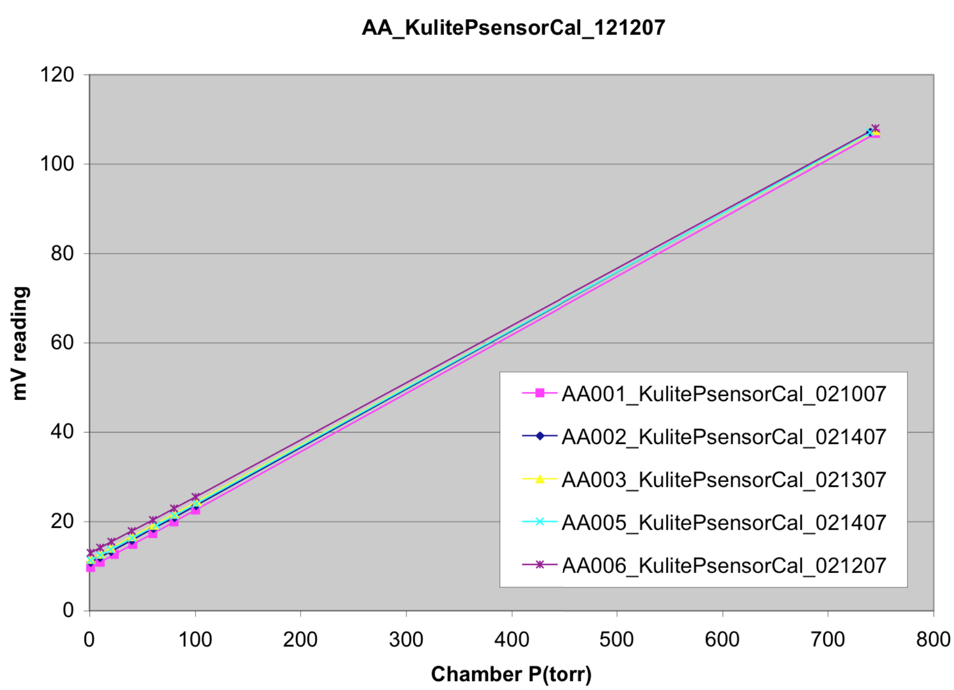
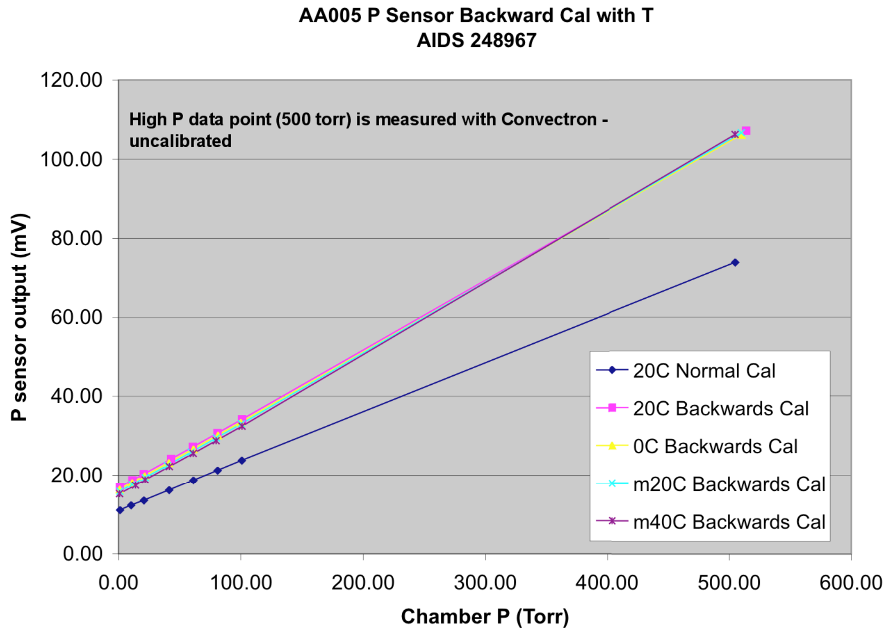


Figure 6. Calibration of AA P sensor output (mV) as a function of chamber pressure at RT. P sensor

drive voltage of 8.2 V. Data obtained with the testbed.

It should be noted that AA005 that is located on WCL cell 3 has a reversed cabling. Therefore, a backwards polarity calibration is required for the P sensor in AA005 (Figure 7).



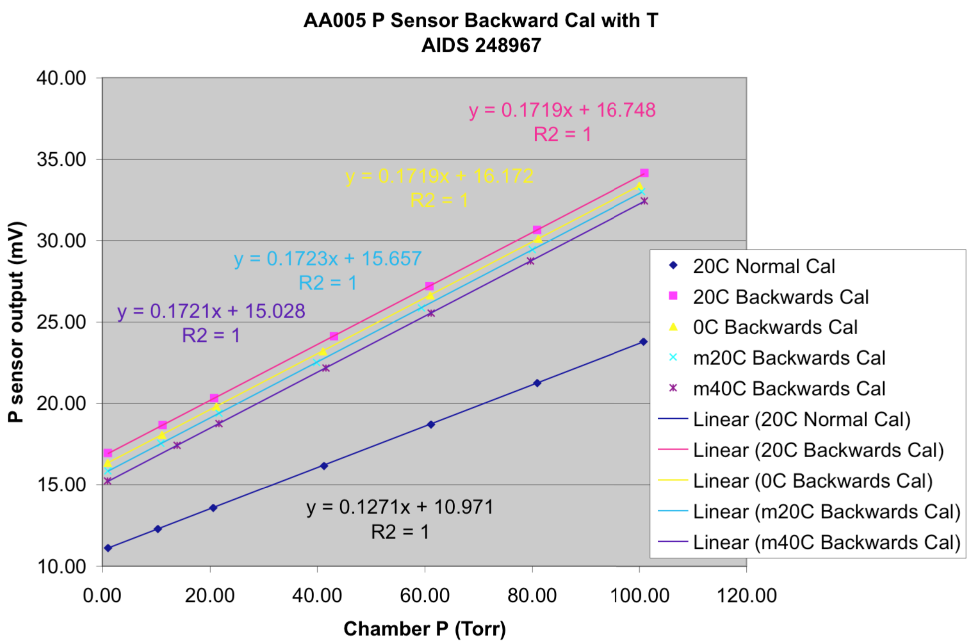


Figure 7. Calibration curve for AA s/n 005. AA s/n 005 is calibrated "backwards" to account for a wiring error that reversed the drive and sense lines. The lower panel shows the calibration curve as a function of temperature to check temperature compensation of this wiring idiosyncrasy.

Table 9. Calibration constants for AA P sensors based on RT calibration curves in Figures 6-7. AA005 is calibrated "backwards" to account for a wiring error that reversed the drive and sense lines. Note the equation for pressure is inverted from the figures where P(torr) = m*V(mV)+b.

P(torr)=m*V(mV)+b			
Sensor Location	**Chamber T [^{o}C]**	**Slope (m) [torr/mV]**	**Intercept (b) [torr]**
AA002	20	7.698	-80.11
AA003	20	7.734	-88.69
AA006	20	7.819	-99.75
AA005 (Backwards)	20	5.817	-97.43
	0	5.817	-94.08
	-20	5.804	-90.87
	-40	5.811	-87.32

During thermal vacuum testing of the actuator assemblies (AIDS 248853), a full end-to-end calibration was performed for AA005 using the flight analog board (s/n 101). At this point of integration, AA005 populated cell position 2 and therefore the drive and sense lines were wired appropriately. Figure 8 reports the end-to-end calibration of the pressure sensor from digital numbers to pressure.

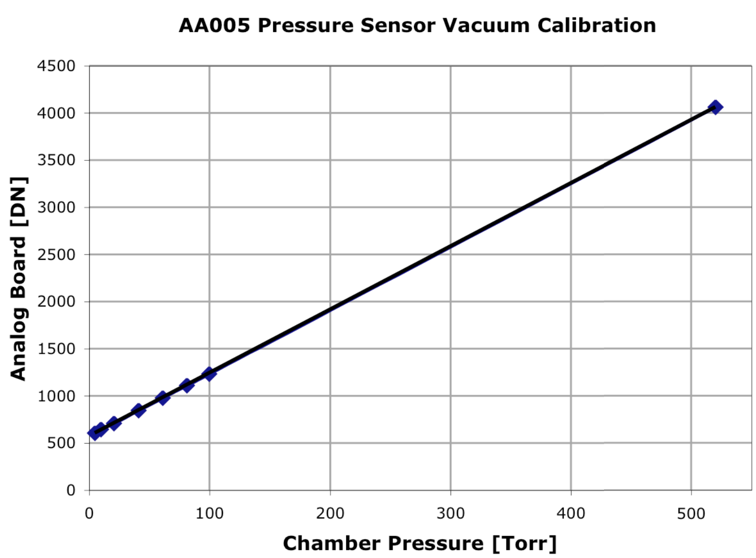


Figure 8. End to end calibration of AA005 with normal wiring of sense and drive lines during thermal-vacuum testing. Results presented in AIDS 248853. It should be noted that the analog board saturates at 4095 DN. Data is fit to a linear model where DN = 6.707*P(torr)+573.9.

Due to a change the gain setting for the P sensor on the flight analog board, previous DN to mV conversions were invalidated from the test bed. From a linear fit of the TV data

(Figure 8) and the normal wiring of AA005 from Figure 6, the analog board calibration is extracted and presented in Table 10.

Table 10. Extracted calibration of analog board to mV for the P sensor from results of Figures 6 and 8 for normal wiring of AA005.

V(mV)=m*DN+b	
Slope (m) [mV/DN]	Intercept (b) [mV]
0.0193	-0.1091

Results of Table 10 are used to extract the digital number to pressure conversion for the flight AA. For the flight units, AA005 populates cell 3 and therefore has reverse wiring.

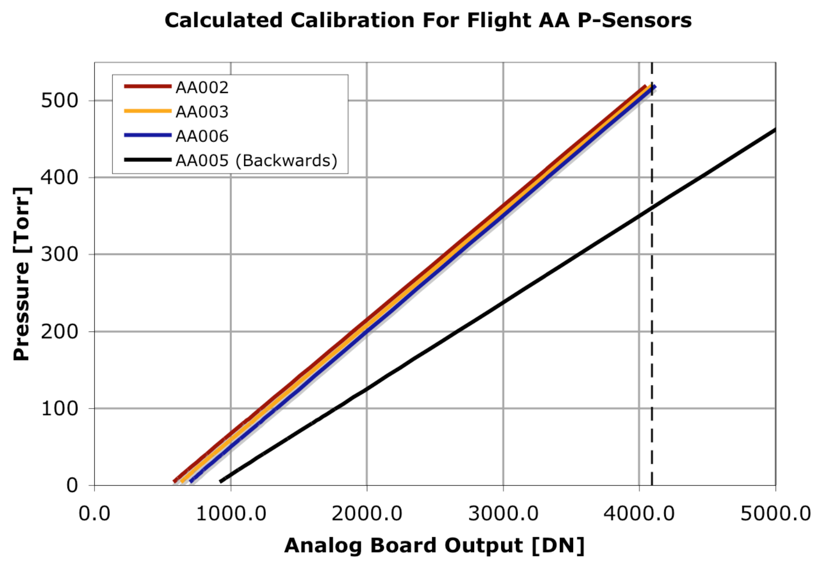


Figure 9. Calculated calibration of the flight AA P-sensors.

Table 11. Tabulated results from the calculated linear model for the flight AA P-sensors.

P(torr)=m*DN+b		
Sensor Location	Slope (m) [torr/DN]	Intercept (b) [torr]
AA002	0.1484	-80.95
AA003	0.1491	-89.54
AA006	0.1507	-100.6
AA005 (Backwards)	0.1122	-98.06

7. Beaker and Actuator Assembly Temperature Sensors

Figure 10 presents results of thermal vacuum calibration of the WCL before delivery to Lockheed Martin immediately prior to integration. The flight WCL hardware was not present during this calibration. Three electrical and mechanical simulators and the spare AA and MSP'01 heritage beaker populated the cell positions. The stage temperature is monitored regardless of the cell position by a resistance temperature detector (RTD) affixed to the base plate near he AFM platform. The calibration data was corrected from the original chamber set point temperature by the chamber thermocouple. This establishes the stage temperature sensor as the gold standard for in-cruise calibration of the flight WCL units.

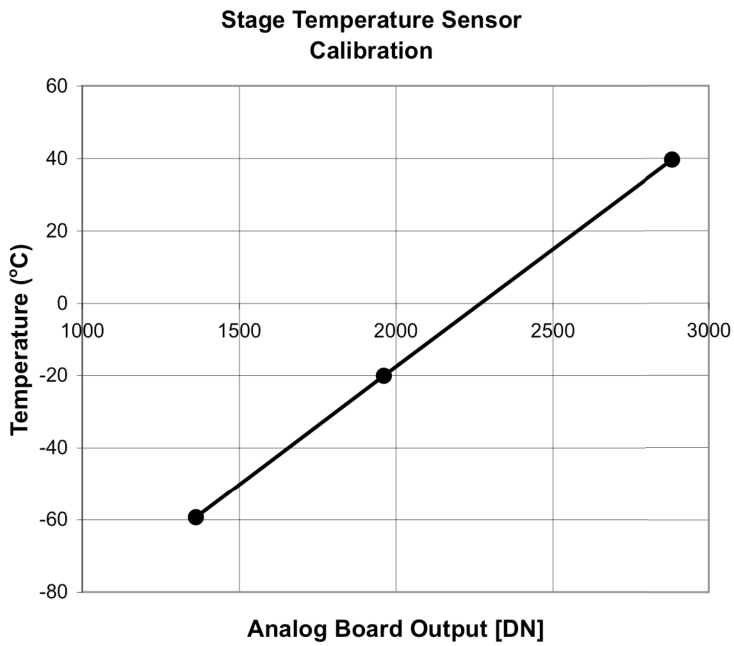


Figure 10. Temperature calibration of the stage temperature sensor before delivery to LM. Calibration did not include flight hardware. Three positions contained the electrical and mechanical simulators and the forth position was populated with the spare AA and MSP'01 heritage beaker.

Calibration of the WCL temperature sensors on the drawer, tank and beaker were expected to be calibrated during cruise. Due to integration of the WCL units after delivery, these units were unable to be calibrated with final connections. The temperature sensor on the MECA stage was calibrated before delivery was meant to serve as the gold standard for the in-cruise calibration (Figure 10).

After the beginning of surface operations, a considerable amount of electrical noise and offsets were observed. A detailed analysis (see full results in Appendix X) was performed to derive the best calibration for the WCL temperature sensors using all available resources. The desire was a full calibration over the entire temperature range of interest. The best method was found to use the final checkout data from LMA at room temperature and the MECA checkout performed during characterization phase of surface operations on Sol 4. The AD590 thermocouple (T-0074) located on the MECA analog board is used as the gold standard. Figure 11 shows the results of the calibration analysis for all four WCL units. Digital numbers are plotted against the calibration stage temperature and linear models are used for calibration of the WCL T sensors and are tabulated in Table 12. Additional offsets are continuing to be characterized due to electronic interference with heater state.

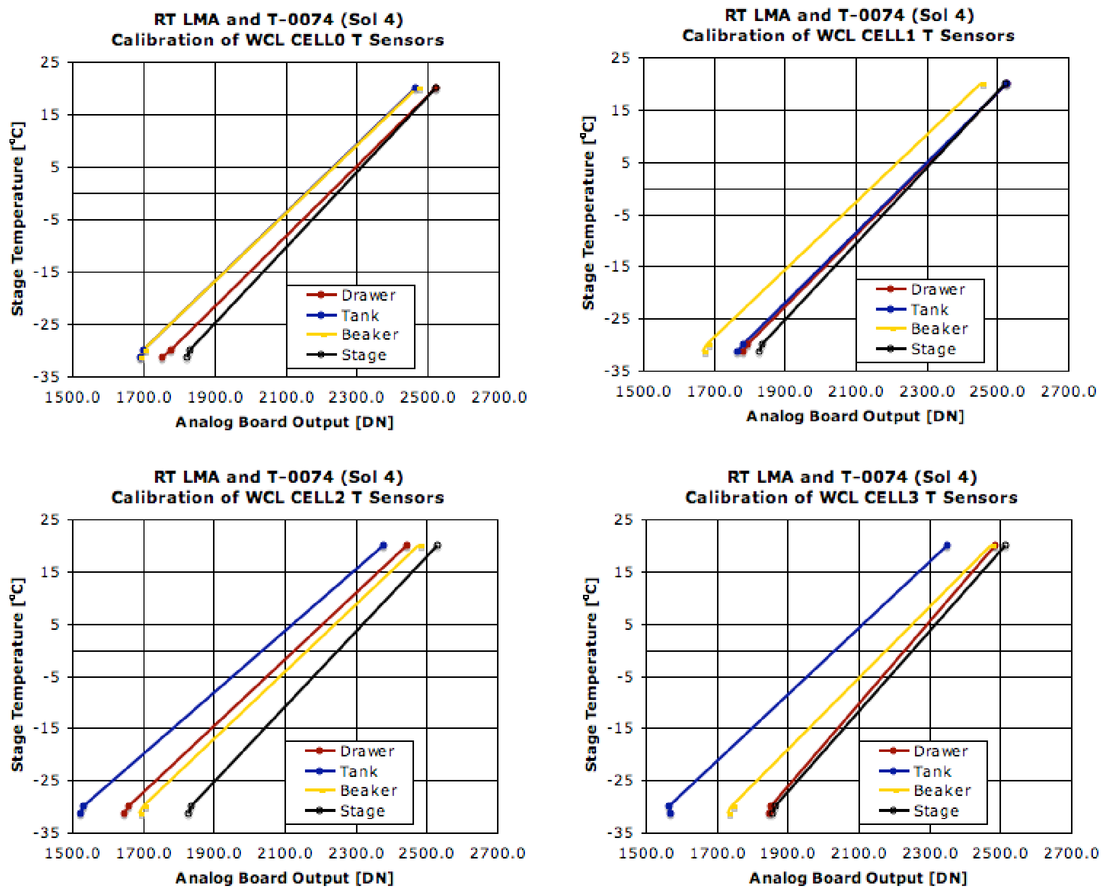


Figure 11. Calibration of the WCL units using the final check out at LMA (RT) and MECA checkout on Sol 4 of surface operations characterization phase. T-0074 is used as the gold standard.

Table 12. Calibration constants for T sensors from Lockheed Martin room temperature bench checkout and T-0074 on Sol 4 of surface operations where T(^oC) = m*DN+b.

T-0074 (sol4) T(^oC)=m*DN+b			
Sensor Location		**Slope (m) [oC/DN]**	**Intercept (b) [oC]**
CELL 0	**Beaker**	0.0655	-141.8
	Tank	0.0660	-142.8
	Drawer	0.0668	-148.6
	Stage	0.0729	-164.0
CELL1	**Beaker**	0.0653	-140.1
	Tank	0.0676	-150.8
	Drawer	0.0688	-153.9
	Stage	0.0735	-165.6
CELL2	**Beaker**	0.0648	-140.6
	Tank	0.0596	-121.8
	Drawer	0.0642	-137.0
	Stage	0.0727	-163.9
CELL3	**Beaker**	0.0686	-149.8
	Tank	0.0647	-132.3
	Drawer	0.0799	-178.7
	Stage	0.0778	-175.6

8. Beaker ISE Sensors

Table 13 lists the 24 sensors that are mounted in the walls of the beaker.

Table 13. List of beaker sensors

	Sensor	Type / Composition
1	Ammonium ($NH4^{+}$)	ISE, PVC membrane doped w/ Nonactin
2	ASV (heavy metals)	512 10 µm Au disk microelectrode array
3	Barium (Ba^{2+})	ISE, PVC membrane doped w/ Ba ionophore-1
4	Bromide (Br^{-})	ISE, Solid pellet crystal
5	Calcium (Ca^{2+})	ISE, PVC membrane doped w/ ETH-1001
6	Chloride (Cl^{-})	ISE, Solid pellet crystal
7	Chloride (REF)	ISE, Solid pellet crystal
8	CP (halides)	1-mm Ag disk electrode
9	CP (halides)	1-mm Ag disk electrode
10	CP (redox/acid/base)	1-mm Pt disk electrode
11	Conductivity	2-electrode (carbon rings)
12	Cyclic Voltammetry (CV)	0.25-mm Au disk electrode
13	Iodide (I^{-})	ISE< Solid pellet crystal
14	Lithium 2 (ref)	ISE, PVC membrane doped w/ Li ionophore-VI
15	Lithium 1 (ref)	ISE, PVC membrane doped w/Li ionophore-VI
16	Magnesium (Mg^{2+})	ISE, PVC membrane doped w/ ETH-7025
17	Nitrate (NO_3^{-})	ISE, PVC membrane doped w/ ion exchanger
18	ORP (Eh, Redox potential)	1-mm Pt disk
19	pH	Iridium electrode coated with iridium oxide
20	pH	ISE, PVC membrane doped w/ ETH-2418
21	pH	ISE, PVC membrane doped w/ ETH-2418
22	Potassium (K^{+})	ISE, PVC membrane doped w/ Valinomycin
23	Sodium (Na^{+})	ISE, PVC membrane doped w/ Na ionophore-VI
24	Temperature	Thermister

Table 14 summarizes the calibrations that were performed at various stages of assembly and testing of the ion sensors. All calibrations were performed at room temperature and pressure.

Table 14. Summary of ISE calibration tests.

Data Set	Test Date	Location	Assembly Stage
--	--	Thermo	Before integration into flight beaker
1	Aug 2007	Thermo	After integration into flight beaker
2	Aug 2007	JPL	As received from Thermo
3	Dec 2007	JPL	After thermal cycling & dynamic protoflight tests
4	Feb 2007	JPL	Calibration before delivery to LMA
5	March 2007	JPL	2^{nd} calibration before delivery to LMA

Before integration into the beaker, Thermo, Corp calibrated each sensor individually in a solution containing only the species of interest to avoid interference and to verify the sensor worked over the required concentration range. The test consisted of measuring the sensor electrode potential in ion solutions of known concentration, referenced against an external silver/silver chloride electrode. (See MECA Wet Chemistry Laboratory Verification and Validation Test Report, Phoenix-565-145, JPL D-37142).

After the integration of the sensors into a beaker, calibrations of all sensors were performed using five test solutions (TS) designated as TS20 through TS24 in Table 15. The TS20 solution is equivalent in composition to the leaching solution in the WCL tank. TS21 is equivalent to the solution in the beaker after the addition of the first crucible containing the calibrants. TS22 through TS24 contain the same ionic species but at increasing concentrations to cover a significant portion of their analytical range. Except for Li^+, NO_3^-, and HCO_3^-, each species is increased by one order of magnitude from 10^{-4} to to10^{-2} M. The Li+ sensors are used as reference electrodes and the Li^+ concentration is kept constant at 10^{-3} M. The Br^- and I^- sensors were not calibrated again after integration into the beaker because the addition of these species would damage the Cl- sensor. The concentration of HCO_3^- is maintained at 10^{-5} M to provide for a constant pH during the calibrations. Note that the Mars (flight) TS21 calibration crucible was not identical to the calibrant TS21 solution. Difference arises from a decision to change the volume of the dispensed solution (30 mL to 25 mL) and a correction to the hydration state of barium chloride and calcium chloride. Calcium chloride dehydrate did not completely dehydrate after 70 hours at 120 degrees. There was an excess of 1.42% water. This is reflected in the difference in concentrations.

Table 15. Composition of calibration solutions for chemical sensors. M-TS21 is the flight calibrant solution based on the composition of the flight crucibles. See section 5.

	Concentration [M]					
Solution Ionic Species	TS20	TS21	TS22	TS23	TS24	M-TS21
	Leaching Solution (LS)	Calibrant Solution	Test Solution	Test Solution	Test Solution	Flight Calibrant Solution
Li^+	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
Na^+	1.00E-05	3.00E-05	1.10E-04	1.01E-03	1.00E-02	3.40E-05
NH_4^+	1.00E-05	3.00E-05	1.00E-04	1.00E-03	1.00E-02	3.40E-05
K^+	1.00E-05	3.00E-05	1.00E-04	1.00E-03	1.00E-02	3.40E-05
Ca^{2+}	1.00E-05	3.00E-05	1.00E-04	1.00E-03	1.00E-02	4.17 E-05
Mg^{2+}	1.00E-05	3.00E-05	1.00E-04	1.00E-03	1.00E-02	3.47E-05
Ba^+	1.00E-05	3.00E-05	1.00E-04	1.00E-03	1.00E-02	3.81E-05
HCO_3^-	1.00E-05	3.00E-05	1.00E-05	1.00E-05	1.00E-05	3.40E-05
Cl^-	5.00E-05	1.50E-04	6.00E-04	6.00E-03	6.00E-02	1.94E-04
NO_3^-	1.03E-03	1.09E-03	1.30E-03	4.00E-03	3.10E-02	1.10E-03

Figures 12 through 15 show calibration curves for eight of the sensors in the four flight beakers. Each line is the average of the five calibrations (data sets 1–5) using the five test solutions. Table 16 summarizes the slope and intercept for the linear fit for each individual sensor and each of the tests.

Table 17 summarizes the differences that were observed in the sensors over the duration of all of the calibration tests. As can be seen in the standard deviation, the individual sensors show similar values for the intercept (E^o) and the slope (S). Tabulations of all calibration data from all 5 data sets (see Table 16) may be found in Appendix B.

On Mars, the sensors will be calibrated *in situ* before the addition of soil. The sensor potentials measured after the leaching solution deployment (equivalent to TS20) and after the first crucible deployment (equivalent to TS21) provide two points for *in situ* calibration. Because the two *in situ* calibration points are at low ion concentrations, Tufts conducted an analysis of various calibration models to assess the error introduced by each potential methodology. Our initial proposition was to use the two *in situ* data points to calculate a new slope and intercept for each sensor. However, the calibration model analysis demonstrated that this, in fact, introduces the most error in the calibration constants, largely due to the fact that the lowest concentration data point resides within the non-linear portion of the ISE response curve for most sensors. The Tufts modeling analyzed the errors introduced by six different calibration models, which are summarized in Table 17. The best results were obtained by using the average slope determined from the five pre-launch calibration data and anchored by the second *in situ* data point. This is consistent with terrestrial experience with ISEs that shows that the least-likely-to-change-with-time calibration constant is the slope. The details of the modeling analysis are in Appendix C (WCL Flight Unit Calibration Method Comparison).

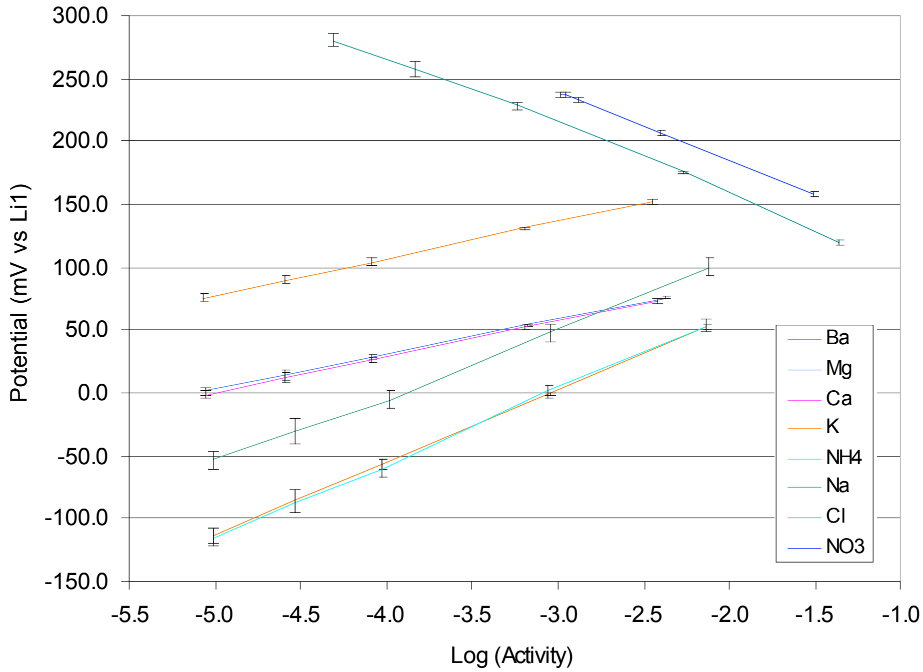


Figure 12. Calibration curves for flight beaker s/n 014.

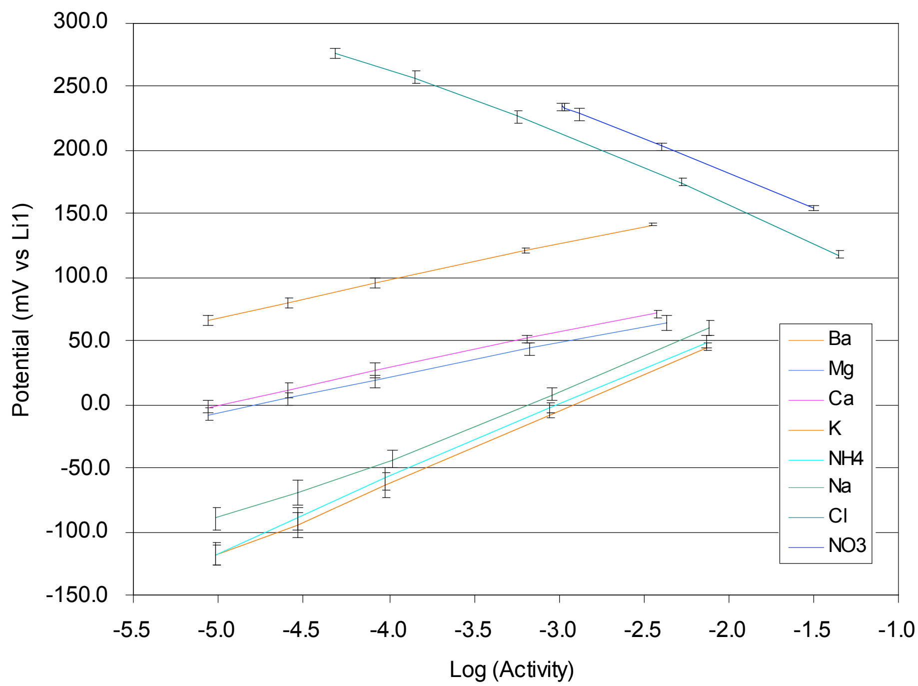


Figure 13. Calibration curves for flight beaker s/n 018.

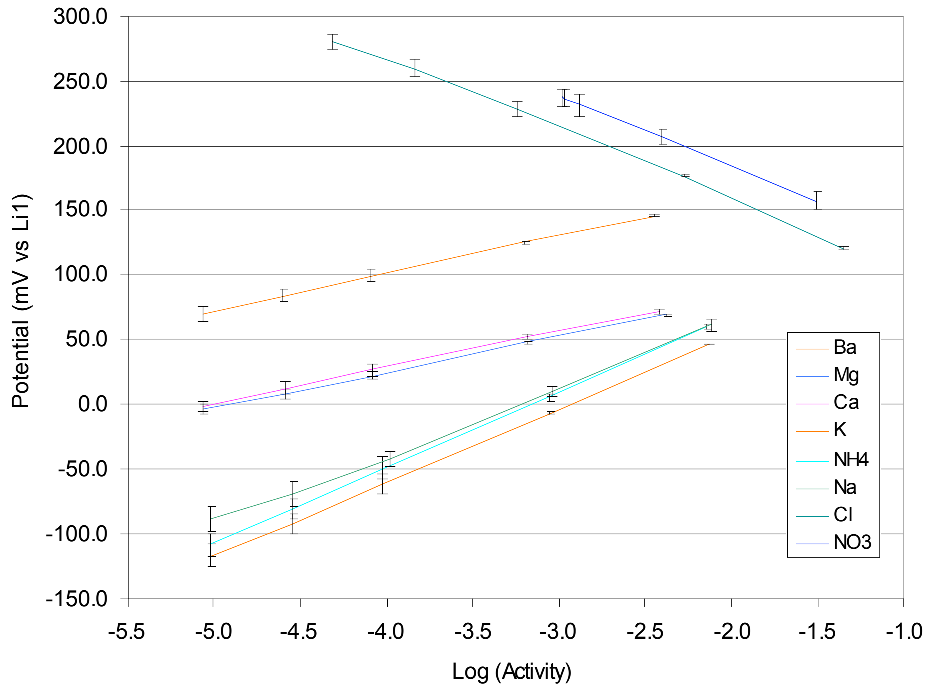


Figure 14. Calibration curves for flight beaker s/n 020.

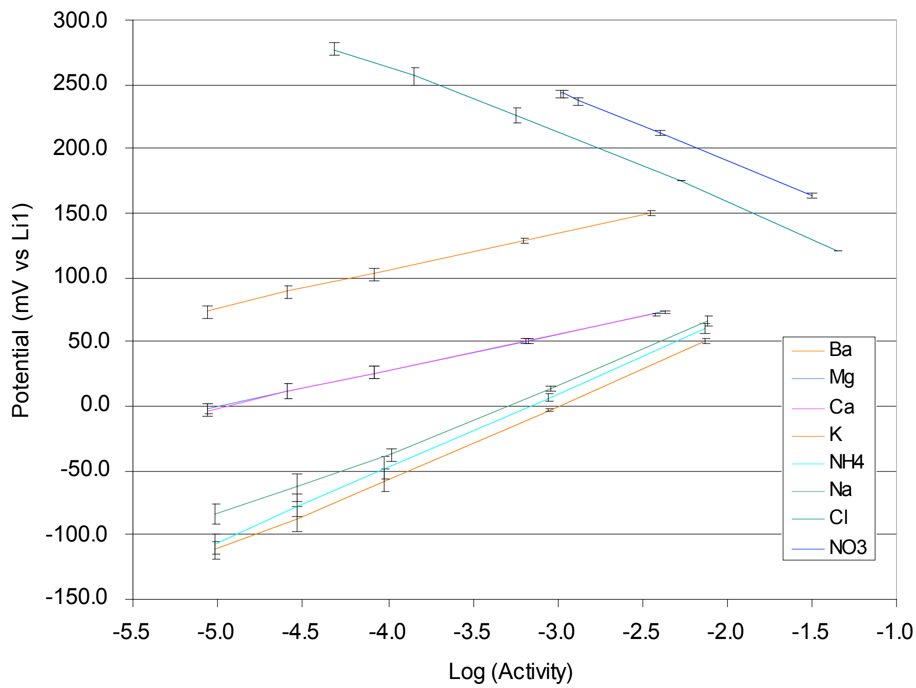


Figure 15. Calibration curves for flight beaker s/n 022.

Table 16. Summary of calibration constants for each ISE for each data set.

	020 - 8/8/06		018 - 8/8/06		022 - 8/8/06		014 - 8/8/06	
	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]
Na^+	54.4	170	53.0	163	53.7	173	54.2	202
$NH4^+$	58.9	184	57.5	169	58.4	182	58.4	171
K^+	58.7	172	57.5	166	58.6	174	58.8	176
Ca^{2+}	29.3	144	28.9	139	28.6	139	28.8	141
Mg^{2+}	28.8	138	28.0	122	28.8	140	29.0	144
Ba^{2+}	29.9	220	29.1	213	29.6	225	29.5	227
NO_3^-	-58.3	70.2	-58.5	60.4	-58.9	69.4	-57.9	65.8
Cl^-	-54.9	49.6	-54.6	44.7	-54.4	49.9	-55.5	47.1

JPL AS RECEIVED

	020 - 8/29/06		018 - 8/29/06		022 - 8/28/06		014 - 8/31/06	
	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]
Na^+	52.7	167	52.6	164	53.4	176	53.0	203
$NH4^+$	59.4	191	59.3	183	59.9	195	57.6	173
K^+	55.5	162	55.9	158	56.1	167	55.5	168
Ca^{2+}	27.6	137	28.1	139	29.1	142	28.5	140
Mg^{2+}	27.8	136	27.4	127	28.8	143	27.8	143
Ba^{2+}	28.8	218	29.5	216	30.3	228	29.5	226
NO_3^-	-60.2	63.8	-59.7	60.4	-58.9	69.6	-59.6	62.2
Cl^-	-55.1	47.9	-54.5	46.7	-54.2	50.9	-55.0	48.0

JPL AFTER PROTOFLIGHT

	020 - 12/12/06		018 - 12/11/06		022 - 12/13/06		014 - 12/13/06	
	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]
Na^+	52.6	172	52.6	171	52.0	174	53.4	210
$NH4^+$	60.4	187	60.5	178	59.3	185	60.1	180
K^+	58.6	172	58.6	172	57.5	172	58.1	175
Ca^{2+}	28.4	142	28.3	142	29.0	144	28.1	141
Mg^{2+}	27.7	134	26.6	125	27.6	139	27.8	142
Ba^{2+}	30.0	219	29.2	213	30.0	223	29.7	225
NO_3^-	-59.1	58.5	-59.3	56.3	-58.0	70.0	-59.1	62.1
Cl^-	-54.7	49.3	-54.2	48.7	-53.8	50.7	-55.3	47.6

JPL FUNC TESTS

	020 - 2/22/07		018 - 2/25/07		022 - 2/22/07		014 - 2/21/07	
	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]
Na^+	47.6	161	48.1	163	47.9	166	50.1	205
$NH4^+$	52.2	169	52.4	162	52.2	170	55.1	174
K^+	51.8	155	52.1	157	52.0	162	53.2	165
Ca^{2+}	25.1	135	25.0	135	25.0	133	25.3	134
Mg^{2+}	24.7	128	24.2	120	24.8	132	25.6	137
Ba^{2+}	25.2	208	25.7	205	25.4	211	26.8	217
NO_3^-	-57.1	60.1	-56.7	60.8	-57.6	69.5	-57.9	61.9
Cl^-	-49.3	58.1	-49.6	57.3	-49.1	57.8	-51.7	54.8

JPL FINAL

	020 - 3/6/07		018 - 3/6/07		022 - 3/6/07		014 - 3/6/07	
	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]	Slope [mV/decade]	Intercept [mV]
Na^+	53.7	177	53.6	178	54.7	183	54.7	220
$NH4^+$	61.0	192	59.8	178	60.3	189	60.6	187
K^+	59.7	174	60.9	177	59.1	178	59.4	181
Ca^{2+}	29.4	145	29.5	147	29.2	143	29.4	146
Mg^{2+}	28.9	139	28.0	129	28.8	142	28.5	145
Ba^{2+}	30.4	219	29.6	213	30.3	222	30.1	226
NO_3^-	-57.7	56.6	-58.0	57.3	-57.6	66.8	-58.8	60.1
Cl^-	-55.4	49.0	-54.6	50.0	-54.1	50.4	-55.4	48.3

Table 17. Summary of differences observed between sensors for all flight beakers over all data sets.

Unit	CELL0 020 Slope [mV/decade]	Intercept [mV]	STDEV [mV/decade]	CELL1 018 Slope [mV/decade]	Intercept [mV]	STDEV [mV/decade]
Na^+	52.2	170	2.7	52.0	168	2.2
NH_4^+	58.4	185	3.6	57.9	174	3.3
K^+	56.9	167	3.3	57.0	166	3.3
Ca^{2+}	28.0	141	1.8	28.0	140	1.8
Mg^{2+}	27.6	135	1.7	26.8	125	1.6
Ba^{2+}	28.9	217	2.1	28.6	212	1.7
NO_3^-	-58.5	61.9	1.2	-58.4	59.0	1.2
Cl^-	-53.9	50.8	2.5	-53.5	49.5	2.2

Unit	CELL2 022 Slope [mV/decade]	Intercept [mV]	STDEV [mV/decade]	CELL3 014 Slope [mV/decade]	Intercept [mV]	STDEV [mV/decade]
Na^+	53.3	174.4	3.3	53.4	211.2	1.9
NH_4^+	58.1	184.2	3.4	59.0	179.8	2.3
K^+	57.1	170.6	3.2	57.9	176.0	2.6
Ca^{2+}	28.2	140.2	1.8	28.1	141.6	1.6
Mg^{2+}	28.0	139.2	1.8	27.9	142.8	1.3
Ba^{2+}	29.1	221.6	2.1	29.3	224.2	1.4
NO_3^-	-58.3	68.8	0.7	-58.7	62.2	0.8
Cl^-	-55.4	43.8	1.7	-54.5	48.9	1.8

Table 18. Summary of ISE Calibration Model Analysis.

Cal Model #	Model	Average % Error	Average Standard Deviation
1	Average pre-launch TS 20–24 slope anchored at *in situ* TS 20 point	7.8	0.1
2	Average pre-launch TS 20–24 slope anchored at *in situ* TS 21 point	6.4	0.1
3	Slope based on *in situ* TS 20 and TS 21 points	95.7	1.0
4	Nernstian slope anchored at in situ TS 20 point	23.5	0.2
5	Nernstian slope anchored at *in situ* TS 21 point	15.9	0.1
6	Average pre-launch TS 21–24 slope anchored at *in situ* TS 21 point	23.1	0.2

9. ClO_4^- and Ca^{2+} Calibration

Experimental results from surface operations show a significant change in the "nitrate" ISE. This particular sensor is susceptible to a large number of interferants and shows sensitivity to the following species: ClO_4^-, ClO_3^-, CN^-, NO_2^-, CO_3^{2-}, and NO_3^-. The highest selectivity of this ISE is to perchlorate (ClO_4^-).

A calibration of perchlorate (ClO_4^-) in flight-like beaker s/n 019 using the PST electronics is performed at 7°C. Initially, the state of the beaker is assessed by a calibration of the beaker in TS20-TS24. All ISE were performing nominally.

Calibration of the perchlorate ISE was performed at 7°C using standard addition of $Mg(ClO_4)_2$ (Figure 16). Both the magnesium and perchlorate response are near-Nernstian with slopes of 26 mV/decade and -55 mV/decade respectively. Additionally, a clear drop in potential of the Ca^{2+} ISE is due to the interference of the lipophilic anion (perchlorate) with complex formation. This interference response is -29 mV/decade of the concentration of perchlorate.

Finally, a standard addition of 1 M $CaCl_2$ in the presence of 4 mM $Mg(ClO_4)_2$ is performed. The slope of the Ca^{2+} ISE maps well with the initial calibration of the ISE in test solutions. Therefore, it is recommended that for the perchlorate and calcium ISE, *the pre-flight calibrations be used*. An additional correction is made for the interference of perchlorate by calculating the half the change in log of activity of perchlorate and multiplying by 29 mV/decade. This provides the mV offset that needs to be applied to the Ca^{2+} ISE to obtain proper concentrations.

Additionally, due to the presence of perchlorate, the Ca^{2+} ISE will show Nernstian behavior from $1x10^{-5}$ to $1x10^{-3}$M (Figure 17).

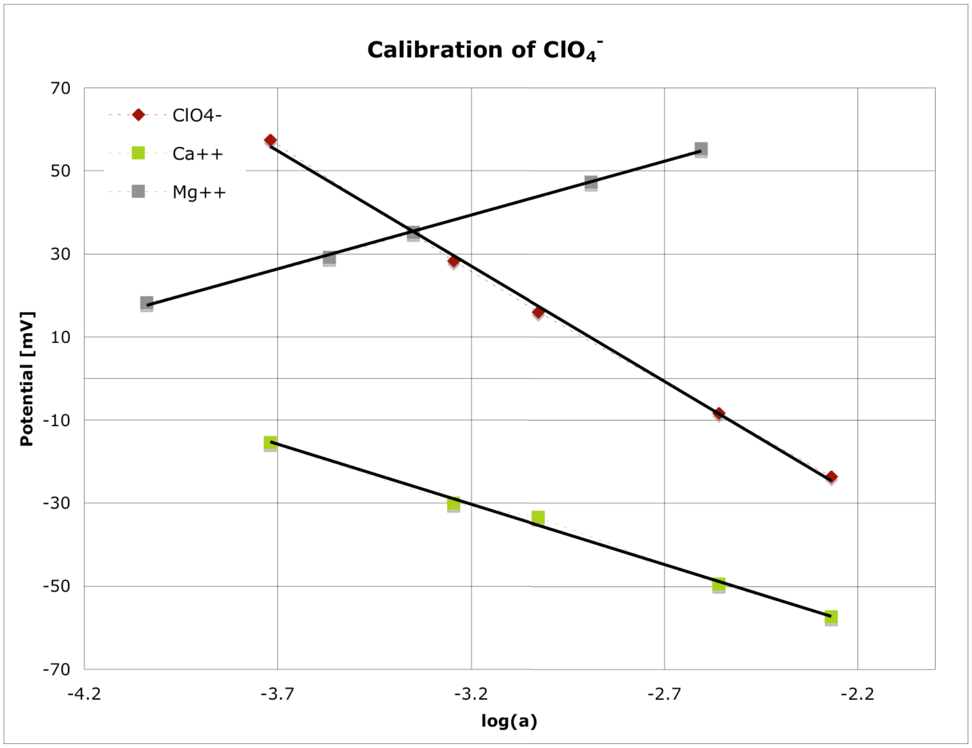


Figure 16. Calibration of the Hofmeister ISE (formally NO_3^- ISE) using standard addition of 0.5 M $Mg(ClO_4)_2$ in M-TS21.

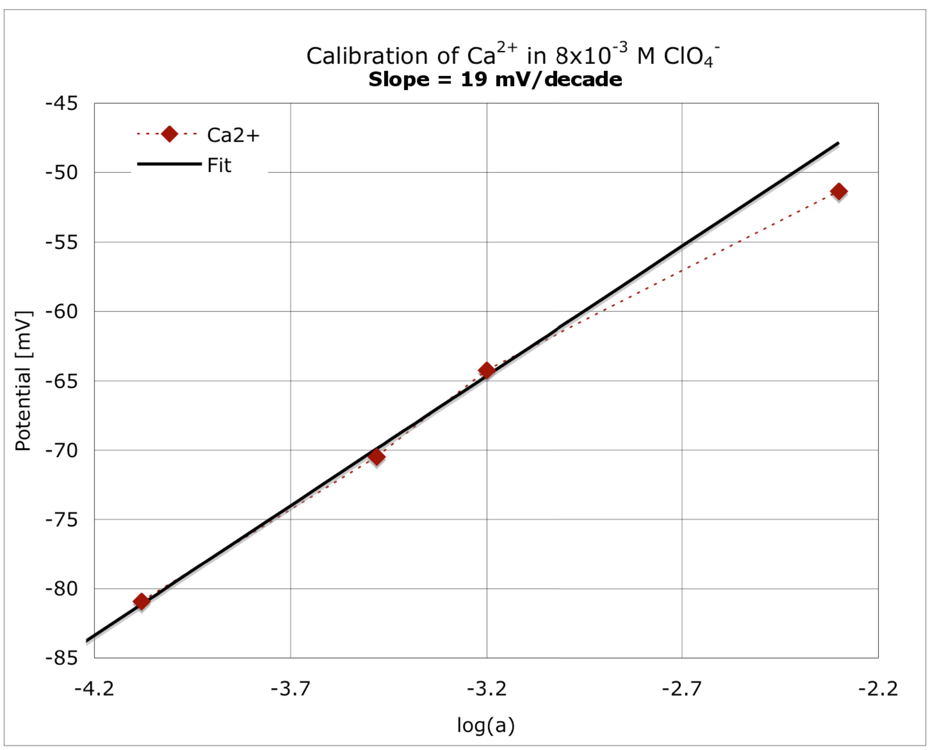


Figure 17. Calibration of Ca^{2+} in the presence of $8x10^{-3}$ M perchlorate by standard addition of 1 M $CaCl_2$

10. Br^- and I^- ISE Sensors

Thermo performed calibration of the bromine and iodide sensors prior to installation into each flight beaker. Standard calibration curves for the Br^- sensor were performed over a concentration range of 10^{-7}M to 1M and show a linear response between 10^{-6}M and 1M. The I^- ISE was calibrated over a concentration range of 10^{-7}M to 10^{-2}M. High concentrations were avoided to evade degradation of the surface. Linear extrapolation of the standard curves is used to obtain further dynamics range. These results are presented in Figures 18 and 19 and results are tabulated in Table 19.

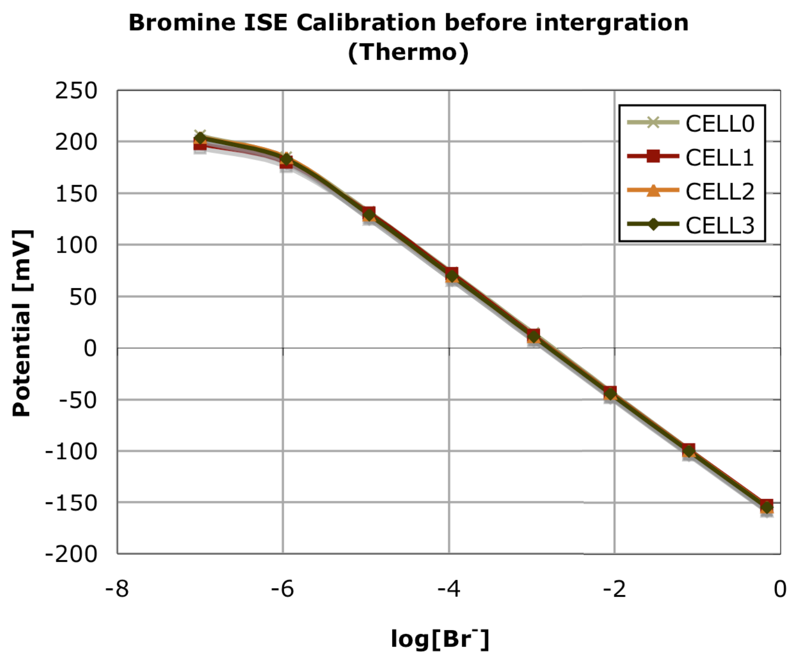


Figure 18. Calibration curve for the flight Br^- ISE before integration into beakers. Note that cell labels refer to final location of the sensor, not its position at the time of calibration.

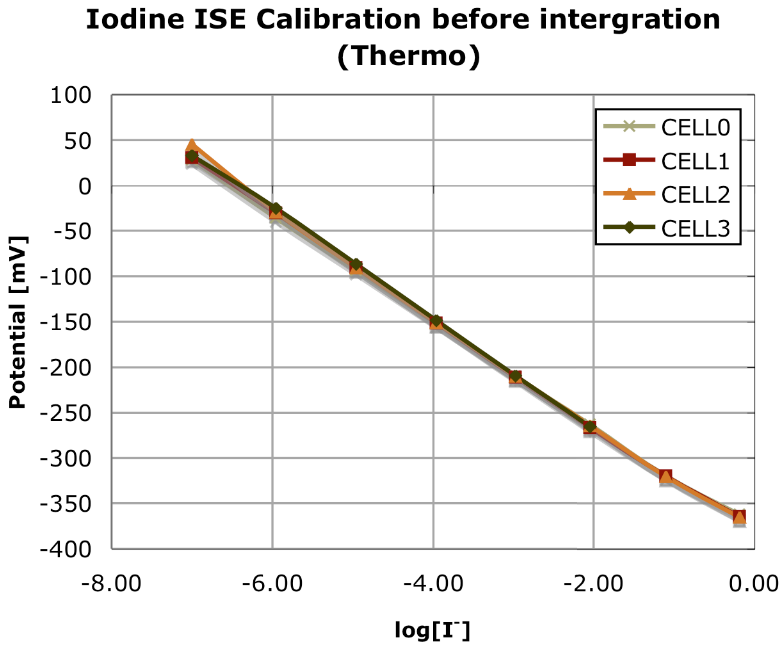


Figure 19. Calibration curve for the flight I^- ISE before integration into beakers. Note that cell labels refer to final location of the sensor, not its position at the time of calibration.

Table 19. Calibration constants for Br- and I- ISEs before integration. (Thermo)

	V(mV)=m*log[Br⁻]+b			V(mV)=m*log[I⁻]+b		
	Br^- ISE ID	**Slope (m) [mV/log[Br^-]]**	**Intercept (b) [mV]**	**I^- ISE ID**	**Slope (m) [mV/log[I^-]]**	**Intercept (b) [mV]**
CELL0	*New #2*	-58.95	-162.7	*New #24*	-58.26	-378.4
CELL1	*Old #15*	-58.30	-162.1	*New #29*	-60.45	-381.9
CELL2	*New #6*	-58.74	-163.7	*New #22*	-60.21	-382.0
CELL3	*New #5*	-58.71	-164.1	*Old #7*	-61.55	-391.8

A final calibration of the integrated sensors could not be conducted since the addition of bromine and iodide into the flight beakers would damage other ISEs. However, as a further test of these sensors, Br^- and I^- ISE measurements using TS 20-24 (test solutions), which contained no added Br- and I-, ions, demonstrate a cross-selective response to other ions, likely to chloride. The selectivity coefficient of the bromide and iodide ISEs can be used to look at specific interferences with other anions. Results are presented in Figure 20.

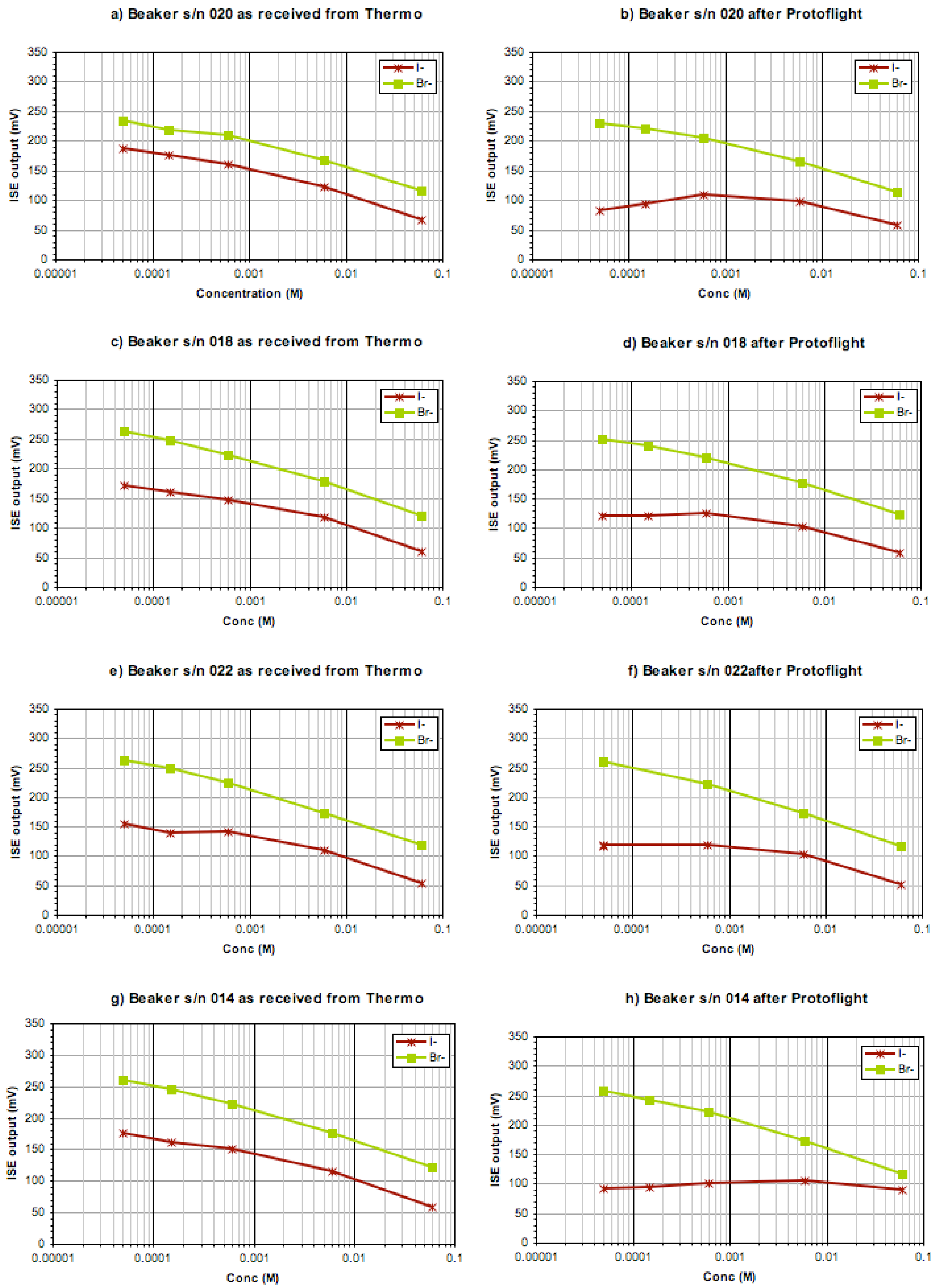


Figure 20. Br^- and I^- ISE measurements for Br^- and I^- in TS test solutions (Table 15). Both sensors show a concentration dependent response due to interference with other ions.

11. pH Sensors

Each beaker contains 2 polymer-based pH sensors and 1 iridium-oxide-based pH sensor. Before integration into the beaker, Thermo calibrated each pH sensor individually using a set of Thermo pH standards (pH 1.68, 4.01, 7.00, 9.18, 10.01).

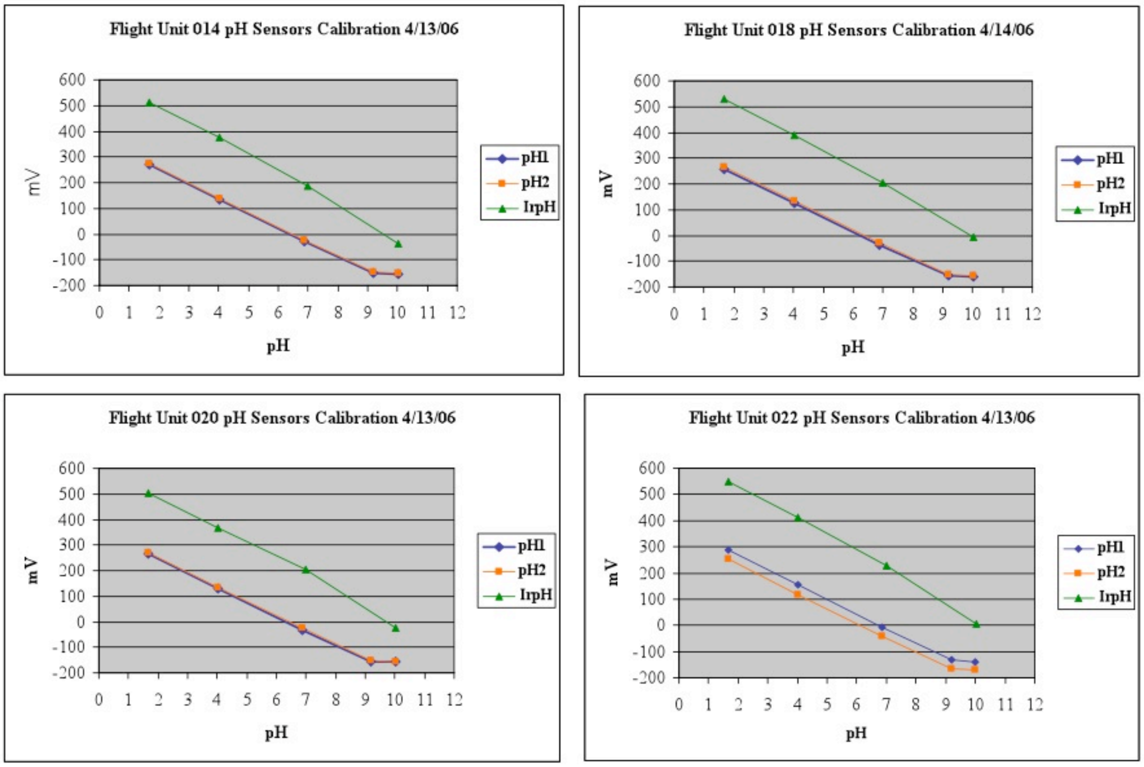


Figure 21. Calibration of the pH sensors before integration to the flight beakers.

Table 20. Calibration of the pH sensors before integration to the flight beakers. pH1 and pH2 are calibration from 1.68 to 9.18 and pH Ir from 1.68 to 7.00. Electrode response departs rapidly from linear beyond these ranges.

	014		018		020		022	
pH Electrodes	**Slope [mV/decade]**	**Intercept [mV]**	**Slope [mV/decade]**	**Intercept [mV]**	**Slope [mV/decade]**	**Intercept [mV]**	**Slope [mV/decade]**	**Intercept [mV]**
pH1	-56.0	361	-55.7	350	-56.3	358	-56.4	382
pH2	-56.1	365	-55.9	360	-56.2	363	-56.0	345
pH Ir	-61.7	620	-61.3	632	-56.7	598	-60.7	652

After integration into the beaker and during the testing of the ISE sensors in the test solution series described in previous section, the output of the pH sensors was also recorded. However, the pH in the test solutions (TS20–24) varies by less than a pH unit and these tests were used more as function tests than calibration tests because of the very narrow pH range accessed. To extend the accessible pH range and avoid placing any solution other than the TS solutions into the beaker, the final calibration tests for pH involved saturating TS21 solution with air and with 5% CO_2, which provided a pH of 6.60 and 5.00, respectively, as measured against an external calibrated commercial pH sensor.

Figure 22 shows representative pH calibration curves for the pH sensors for beaker s/n 014 prior to integration into the beaker. Figure 23 shows the final calibration curves obtained for the integrated beaker s/n 014 using the air and 5% CO2 saturated TS21 solution. The slope and intercept for all of the pH sensors in all flight beakers from the final calibration data set using air and CO_2 saturated TS21 solution is summarized in Table 21.

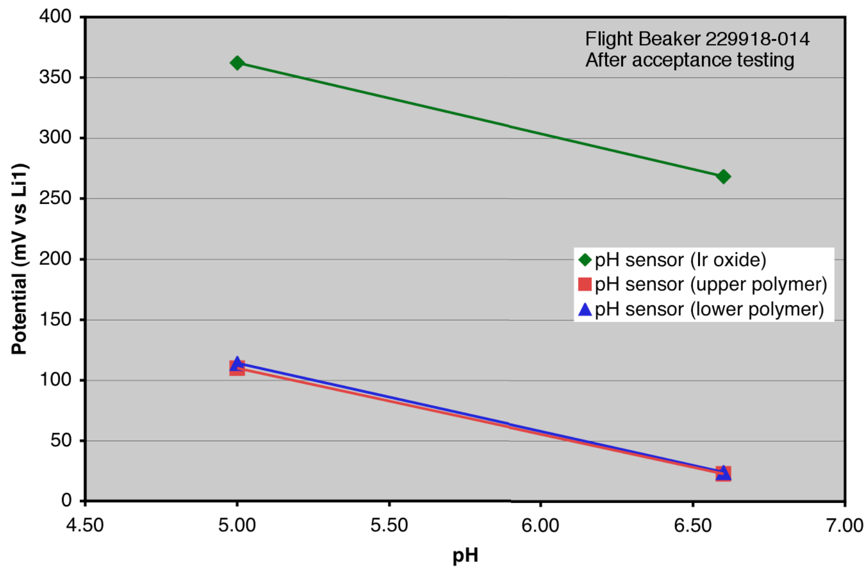


Figure 22. Calibration curve for pH sensors for beaker s/n 014 before integration into the beaker.

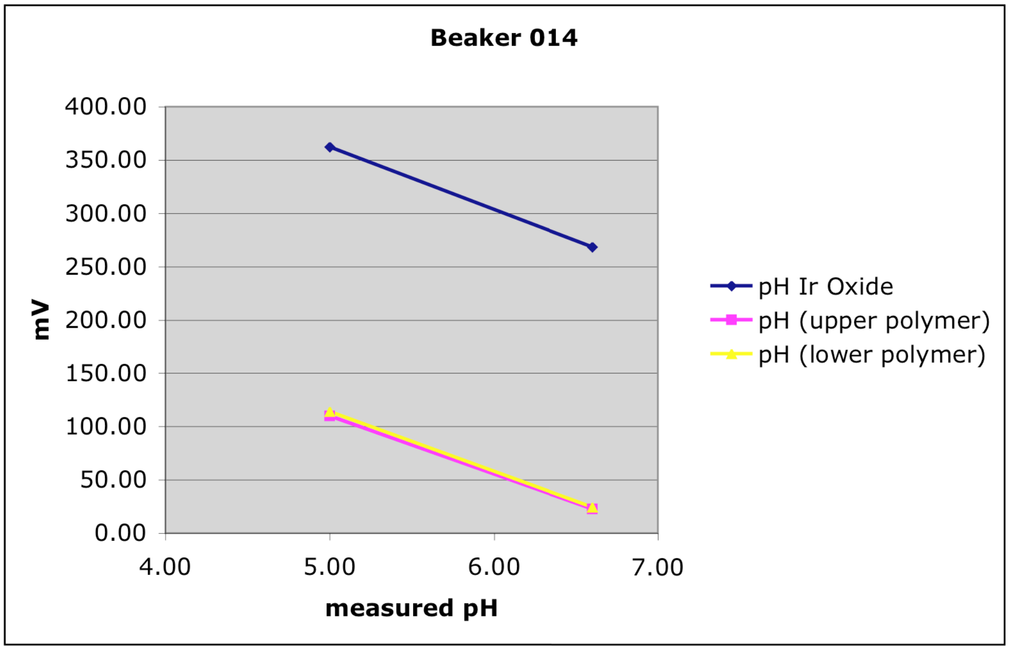


Figure 23. Calibration results for pH sensors for beaker s/n 014 just prior to delivery to LMA. The test range is limited to air-saturated leaching solution and 5% CO_2-saturated leaching solution.

Table 21. Calibration constants for pH sensors in each flight beaker.

Beaker s/n	014		018		020		022	
	Slope (mV/pH)	Intercept (mV)	Slope (mV/pH)	Intercept (mV)	Slope (mV/pH)	Intercept (mV)	Slope (mV/pH)	Intercept (mV)
Ir pH	-58.70	655.89	-56.43	578.19	-52.40	610.16	-52.40	610.79
pH 1 (upper)	-54.55	382.86	-59.35	401.72	-55.97	371.49	-58.11	398.76
pH 2 (bottom)	-56.14	394.89	-59.77	406.98	-57.23	387.74	-55.79	371.52

On Mars, two *in situ* calibration points will be collected before the addition of soil. Similar to the discussion in Section 8, we expect to use the pre-launch slope of the pH sensors and anchor the curve with one or two of the *in situ* calibration points. Further analysis of the error introduced by using one or two of the *in situ* calibration points, similar to that reported in Section 8, remains to be completed. Additionally, because the CO_2 concentration affects the pH of the *in situ* calibration solutions, the analysis must includes operational considerations such as open/closing of the sample drawer.

The data for the pH calibrations for all flight beakers is provided in Appendix C.

12. Analog Board

This section contains the calibration for conversion of the analog board output (DN) to mV for all MECA measurements and pressure and temperature readings. This calibration was performed on the flight analog board (s/n 102).

12.1. ISEs

Conversion of digital output (DN) to ISE potential (mV) is performed by utilizing a simple circuit that accurately models the output impedance of the ISEs. Electrically buffered ISEs located in the beaker have a single characteristic relationship between DN and mV and a single slope and intercept can accurately define the transfer extracted from a linear fit to the (non-saturated) calibration data (Figure 24). Conversion of ISE potential to physical units is presented in the previous section.

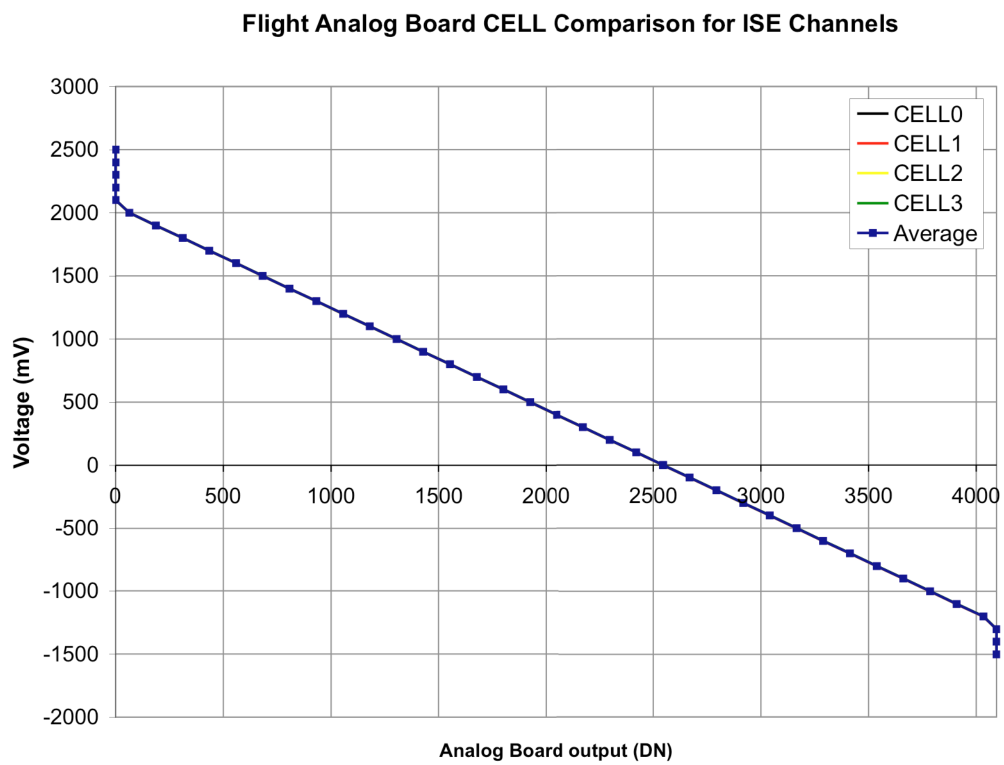


Figure 24. Calibration of the electrically buffered ISE channels for each of the WCL beakers.

Table 22. Calibration of the ISE channels for each flight beaker and the average where V(mV)=m*DN+b. Conversion to absolute potential requires subtraction of the lithium reference electrode.

	Slope (m) [mV/DN]	Intercept (b) [mV]	Std Error
CELL0	-0.8056	2050.85	0.34
CELL1	-0.8062	2050.98	0.11
CELL2	-0.8056	2050.18	0.14
CELL3	-0.8055	2051.07	0.15
Average	***-0.8058***	***2050.88***	***0.15***

It should be noted that a different calibration is required for all reference channels and a third linear model for the oxidation-reduction potential (ORP) electrode. This electrode serves as a ground for all other sensors and therefore $V_{ORP} = - V_{Li}$.

12.2. Conductivity

The calibration for the analog board conductivity circuit is pictorially represented in Figure 25. For conductivity, both the voltage and current are measured separately. The transfer functions for both of these do not go through 0, therefore, a zero-level adjustment of the A/D reading is used for each.

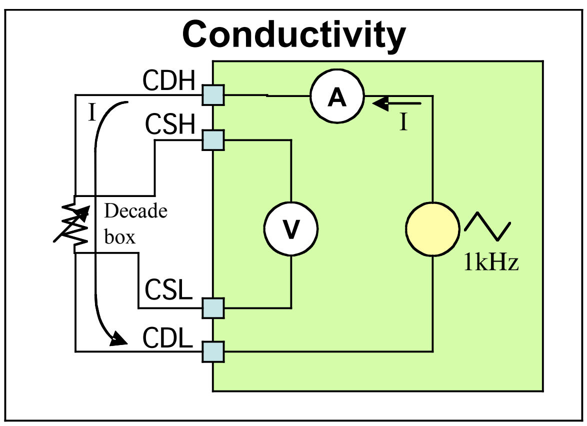


Figure 25. Conductivity calibration configuration

For the calibration, the ratio of the adjusted voltage (DN) to the adjusted current (DN) is linear with respect to resistance. Conductance is derived from the inverse of the resistance (1/R=I/V) and conductivity is obtained by multiplying the conductance by the cell constant.

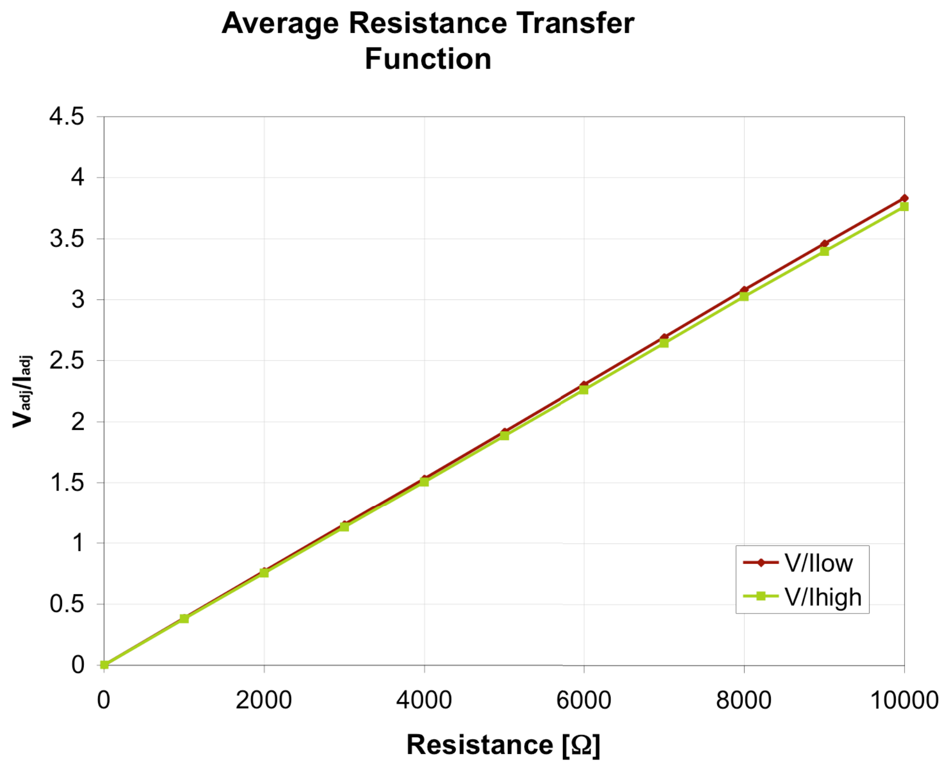


Figure 26. Resistance transfer function calibration curve for the adjusted voltage and current. Plot shows average of all WCL cells.

Table 23. Conductivity calibration tables where $R(\Omega)=a*(V_{adj}/I_{adj})$ where $V_{adj}=b-V[DN]$ and $I_{adj}=c-I[DN]$ Calculated cell constant are determined using standard solutions with known conductivities (Thermo).

	V/I_{low}			V/I_{Ihigh}		
	Slope (a) [Ω]	**V_{adj} (b) [DN]**	**I_{adj} (c) [DN]**	**Slope (a) [Ω]**	**V_{adj} (b) [DN]**	**I_{adj} (c) [DN]**
CELL 0	2608	2545	2560	2655	2545	2556
CELL1	2604	2545	2558	2654	2545	2556
CELL2	2603	2546	2558	2654	2546	2557
CELL3	2603	2545	2558	2650	2545	2555
Average	***2604***	***2545***	***2559***	***2653***	***2545***	***2556***

The cell constant is related to the geometrical dimensions of the "cell." Calibration of the cell constants for each WCL unit is determined by measuring the conductance of a standard solution with a known conductivity. Table 24 shows the nominal conductivity of the standard TS solutions used for calibration of the ISEs, the measured conductivity (G) and the calculated cell constant (k). During surface operations, a second calibration point will be obtained by measuring the conductivity of the leaching solution (TS20) and the solution after reagent addition (TS21). Cell constants are expected to change with aging of the sensor.

Table 24. Calculated cell constant (k) are determined using the standard TS solutions. Where conductivity is the product of the conductance (G) times the cell constant (k). The highlighted solutions will be repeated for each WVL unit as part of the calibration process.

Received from Thermo

	Conductivity (nominal, µS/cm)	014		018		020		022	
		G (µS)	k (cm^{-1})	G (µS)	k (cm^{-1})	G (µS)	k (cm^{-1})	G (µS)	k (cm^{-1})
TS20	*118.60*	78.37	*1.513*	81.25	*1.460*	82.22	*1.442*	80.53	*1.473*
TS21	*142.80*	91.70	*1.557*	94.71	*1.508*	96.71	*1.477*	94.00	*1.519*
TS22	*225.90*	145.76	*1.550*	151.17	*1.494*	154.48	*1.462*	149.27	*1.513*
TS23	*1213.00*	747.31	*1.623*	787.07	*1.541*	819.72	*1.480*	751.03	*1.615*
TS24	*9620.00*	5341.93	*1.801*	5599.33	*1.718*	5985.42	*1.607*	4721.04	*2.038*

After Protoflight

	Conductivity (nominal, µS/cm)	014		018		020		022	
		G (µS)	k (cm^{-1})	G (µS)	k (cm^{-1})	G (µS)	k (cm^{-1})	G (µS)	k (cm^{-1})
TS20	*118.60*	80.33	*1.476*	81.02	*1.464*	81.74	*1.451*	81.60	*1.453*
TS21	*142.80*	96.06	*1.486*	96.90	*1.474*	98.30	*1.453*	80.61	*1.771*
TS22	*225.90*	151.68	*1.489*	153.89	*1.468*	156.53	*1.443*	153.55	*1.471*
TS23	*1213.00*	761.16	*1.594*	798.65	*1.519*	812.55	*1.493*	765.96	*1.584*
TS24	*9620.00*	5156.54	*1.866*	5560.87	*1.730*	5532.89	*1.739*	4584.37	*2.098*

12.3. Chronopotentiometry (CP)

Two digital number (DN) conversions are required for the CP measurement. One defines the digital input for a given current ramp at a specific gain setting (7 total gain settings) and the second digital readout gives the corresponding measured potential (mV). CP is performed on 3 separate electrodes; two Ag electrodes CP1(CPA or CPS1) and CP2 (CPB or CPS1) and a Pt electrode CP3 (CPC or CPP).

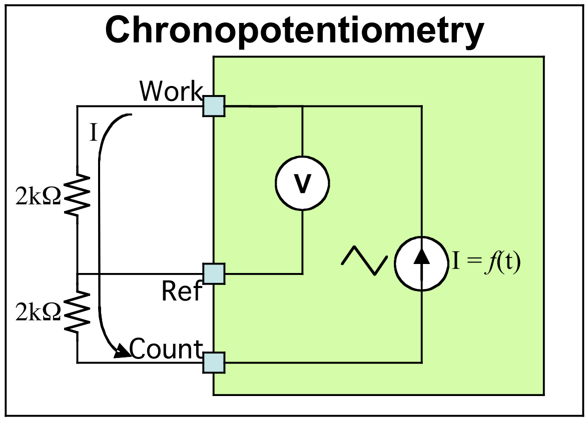


Figure 27. Chronopotentiometry calibration configuration

For a given gain setting, the input current waveform is converted from DN to nA using a linear model defined by a slope and intercept for each of the CP electrodes. It should be noted that the gain settings do not monotonically increase due to the reversal of the bit order of the FPGA.

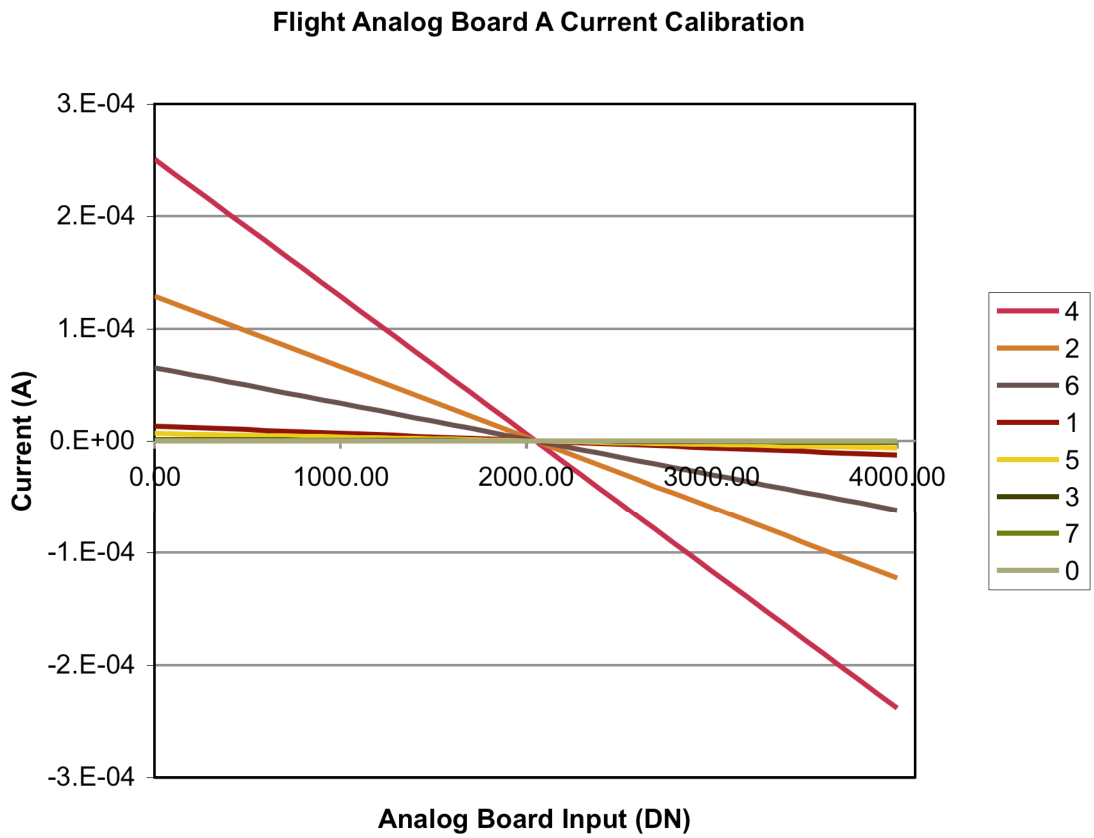


Figure 28. Calibration of DN input to current for the flight analog board (s/n 102) using CP electrode A.

Current (A) I(nA)=m*DN+b				
Gain Setting	**Slope (m) [nA/DN]**	**Intercept (b) [nA]**	**Slope %RSD**	**Intercept %RSD**
4	-122.4	251048	0.0262	0.0560
2	-62.82	128891	0.0118	0.0577
6	-31.81	65278	0.0079	0.0587
1	-6.454	13243	0.0035	0.0589
5	-3.225	6619	0.0102	0.0729
3	-0.6476	1329	0.0162	0.1082
7	-0.3235	663.6	0.0948	0.1726

Table 25. Calibration of DN input to current for the flight analog board (s/n 102) using CP electrode A where I(nA)=m*DN+b.

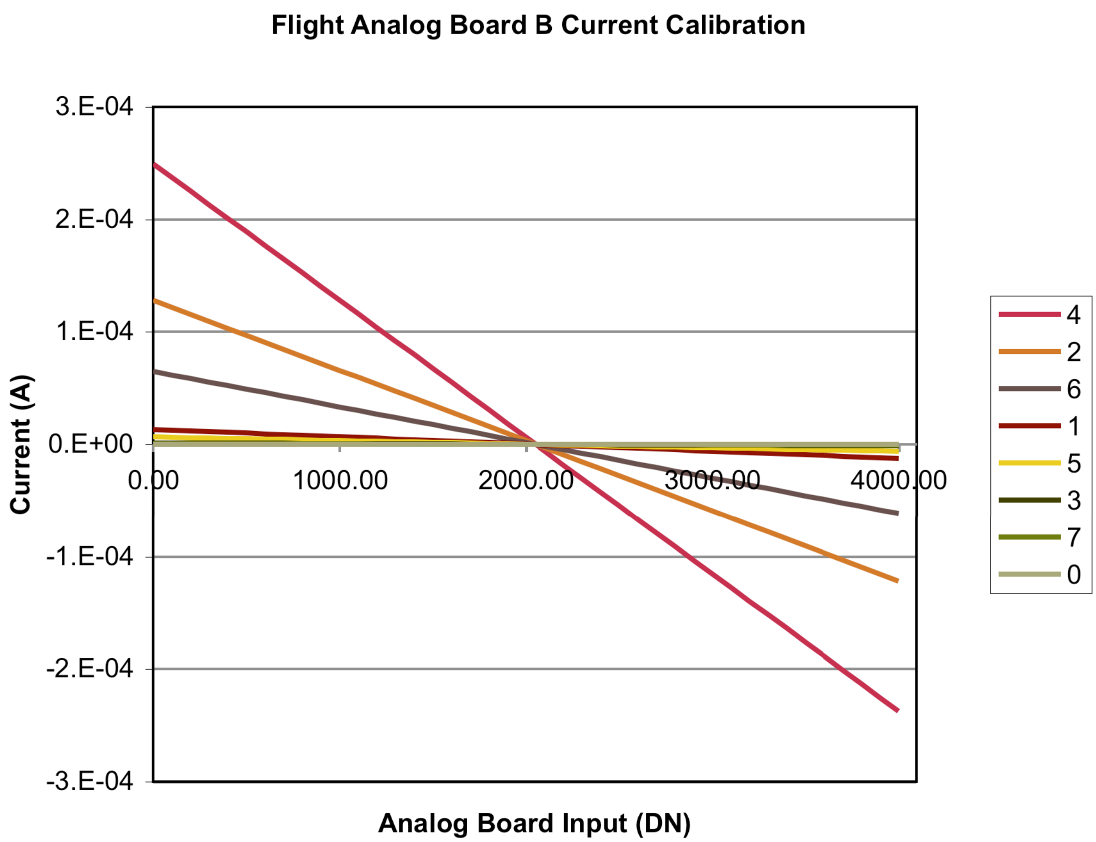


Figure 29. Calibration of DN input to current for the flight analog board (s/n 102) using CP electrode B.

Current (B) I(nA)=m*DN+b				
Gain Setting	**Slope (m) [nA/DN]**	**Intercept (b) [nA]**	**Slope %RSD**	**Intercept %RSD**
4	-121.8	249755	0.0194	0.0576
2	-62.50	128222	0.0088	0.0629
6	-31.65	64939	0.0041	0.0642
1	-6.421	13173	0.0068	0.0703
5	-3.209	6583	0.0176	0.0794
3	-0.6445	1321	0.0313	0.1301
7	-0.3217	658.5	0.0508	0.1341

Table 26. Calibration of DN input to current for the flight analog board (s/n 102) using CP electrode B where I(nA)=m*DN+b.

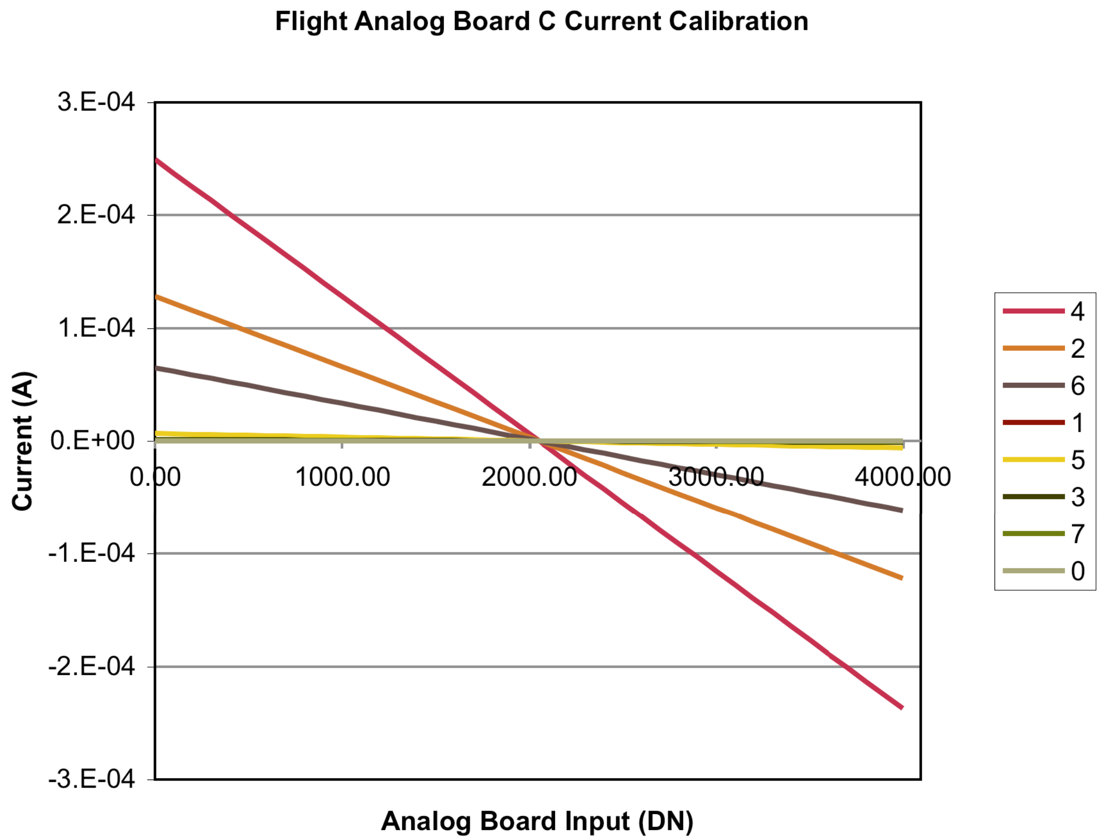


Figure 30. Calibration of DN input to current for the flight analog board (s/n 102) using CP electrode C.

Current (C) I(nA)=m*DN+b				
Gain Setting	**Slope (m) [nA/DN]**	**Intercept (b) [nA]**	**Slope %RSD**	**Intercept %RSD**
4	-121.8	249772	0.0171	0.0596
2	-62.50	128232	0.0079	0.0685
6	-31.65	64942	0.0047	0.0705
1	-6.422	13176	0.0081	0.0804
5	-3.209	6585	0.0140	0.0828
3	-0.6446	1322	0.0421	0.0977
7	-0.3216	659.5	0.0581	0.1338

Table 27. Calibration of DN input to current for the flight analog board (s/n 102) using CP electrode C where I(nA)=m*DN+b.

The output voltage is converted from the digital readout for the three CP electrodes using an independent linear model for each. The calibration curves are plotted in Figure 31 and the extracted slope and intercept are tabulated in Table 28.

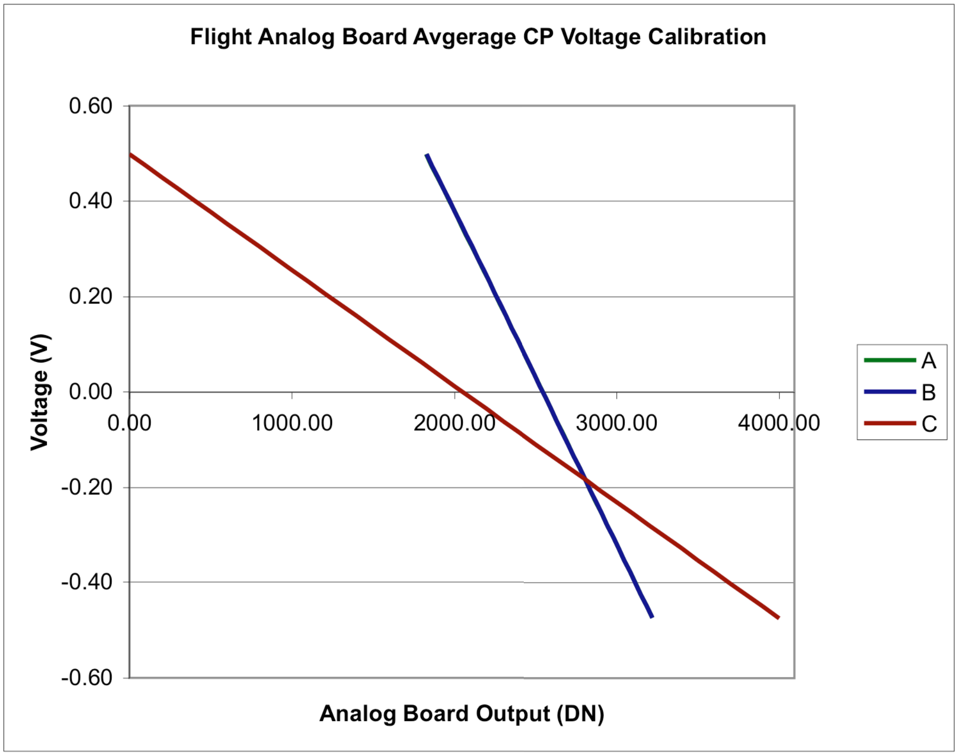


Figure 31. Calibration of DN output to measured potential for the flight analog board (s/n 102) for all three CP electrode (A, B and C).

Output Voltage V(mV)=m*DN+b				
Electrode Input	**Slope (m) [mV/DN]**	**Intercept (b) [mV]**	**Slope %RSD**	**Intercept %RSD**
A	-0.6985	1777	0.2678	0.2553
B	-0.6996	1780	0.1038	0.0866
C	-0.7062	1796	0.0595	0.0664

Table 28. Calibration of DN output to measured potential for the flight analog board (s/n 102) for all three CP electrode (A, B and C) where V(mV)=m*DN+b.

12.4. Voltammetry

Similar to the CP measurement, two digital number (DN) conversions are required for the voltammetry. The digital input defines the drive voltage waveform and the digital readout gives the resultant current for a specified gain setting (6 total gain settings, gain settings 0 and 4 are zero). Voltammetry is performed on three separate input electrodes; dissolved oxygen (DOX), cyclic voltammetry (CV) and anodic stripping voltammetry (ASV).

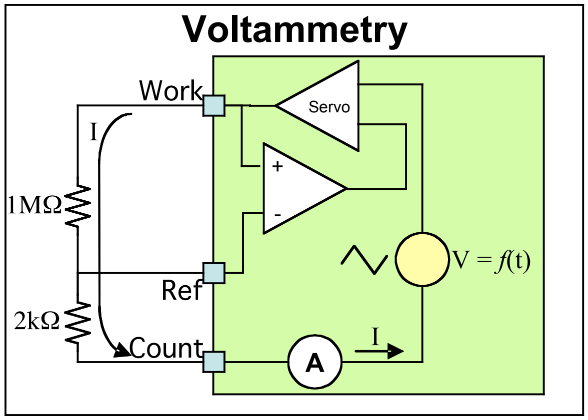


Figure 32. Voltammetry calibration configuration

For a given gain setting, the output current is converted from DN to nA using a linear model defined by a slope and intercept for each of the voltammetry electrodes. It should be noted that the gain settings do not monotonically increase due to the reversal of the bit order of the FPGA and that these gain settings do not correspond to the same electronics as for CP.

12.4.1. Dissolved Oxygen (DOX)

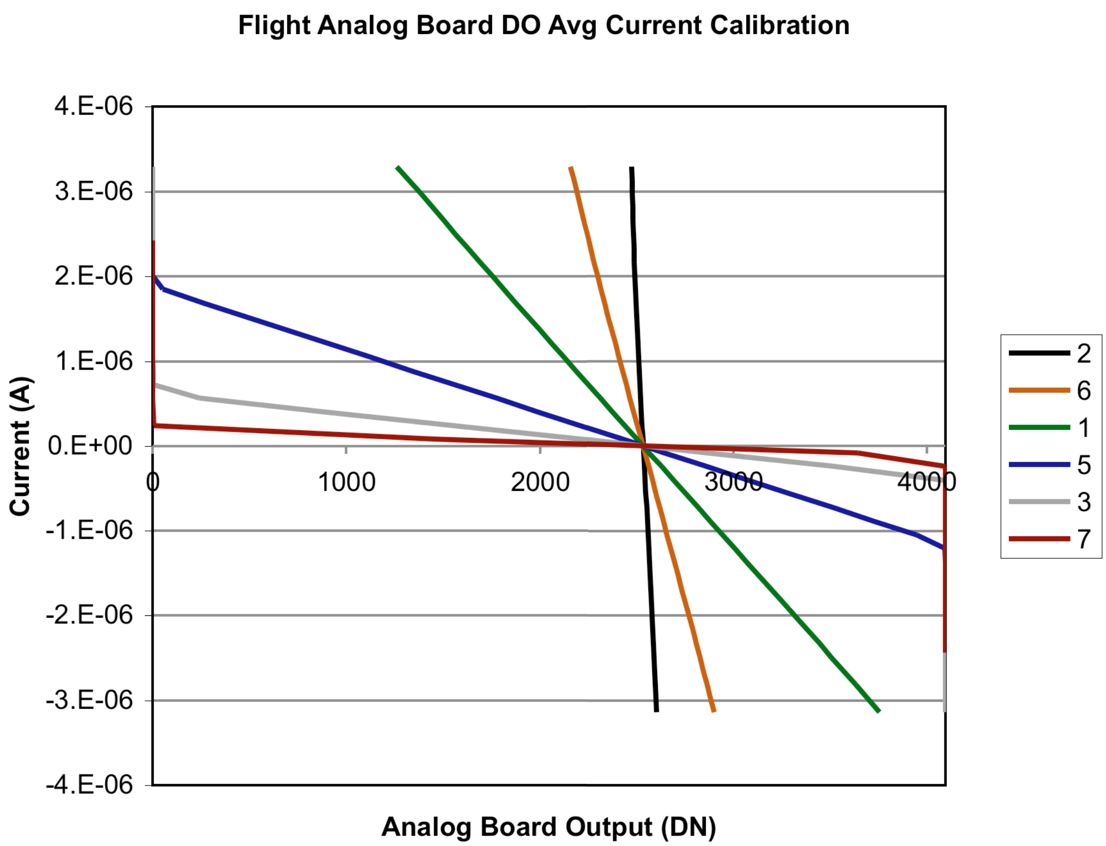


Figure 33. Calibration of DN output to current for the flight analog board (s/n 102) for the dissolved oxygen measurement.

DOX I(nA)=m*DN+b				
Gain Setting	**Slope (m) [nA/DN]**	**Intercept(b) [nA]**	**Slope %RSD**	**Intercept %RSD**
2	-46.97	1.191E+05	0.67	0.70
6	-8.576	2.174E+04	0.09	0.16
1	-2.571	6518	0.04	0.15
5	-0.7435	1883	0.01	0.15
3	-0.2457	622.5	0.01	0.16
7	-0.0735	186.3	0.06	0.17

Table 29. Calibration of DN output to current for the flight analog board (s/n 102) for the dissolved oxygen measurement where I(nA)=m*DN+b.

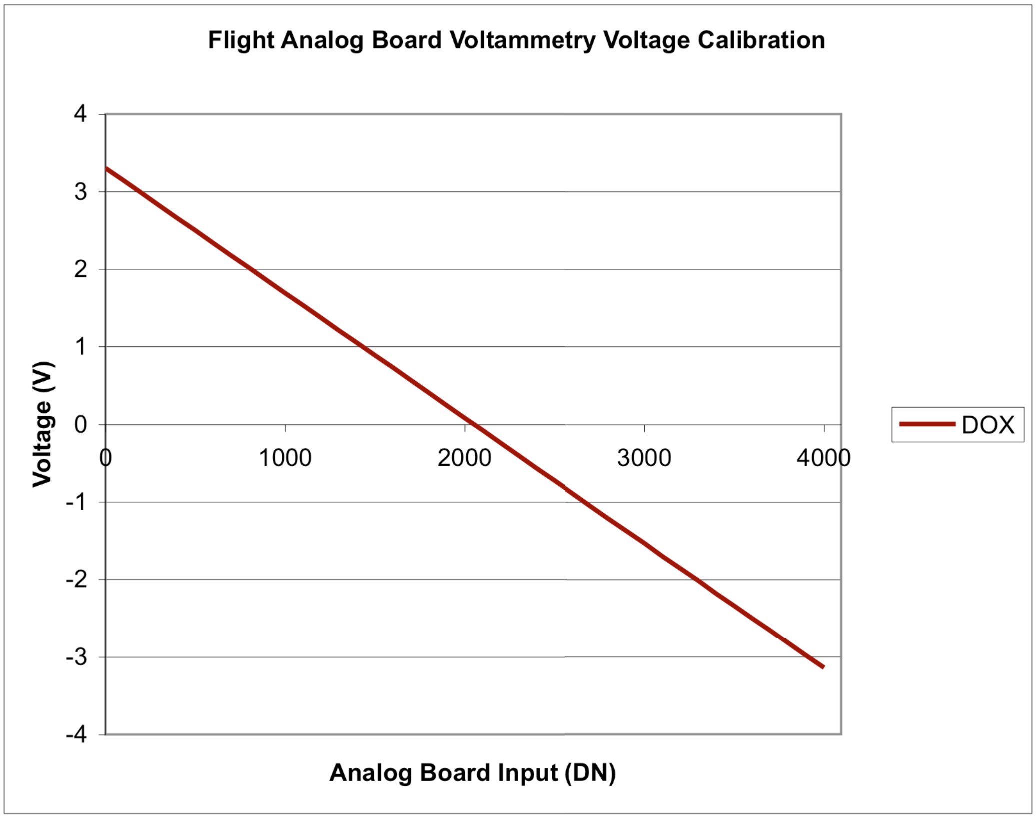


Figure 34. Calibration of DN input to voltage (mV) for the flight analog board (s/n 102) for the dissolved oxygen measurement.

V(mV)=m*DN+b				
Electrode Input	**Slope (m) [mV/DN]**	**Intercept(b) [mV]**	**Slope %RSD**	**Intercept %RSD**
DOX	-1.614	3306	0.01	0.02

Table 30. Calibration of DN output to voltage (mV) for the flight analog board (s/n 102) for the dissolved oxygen measurement where V(mV)=m*DN+b.

12.4.2. Cyclic Voltammetry (CV)

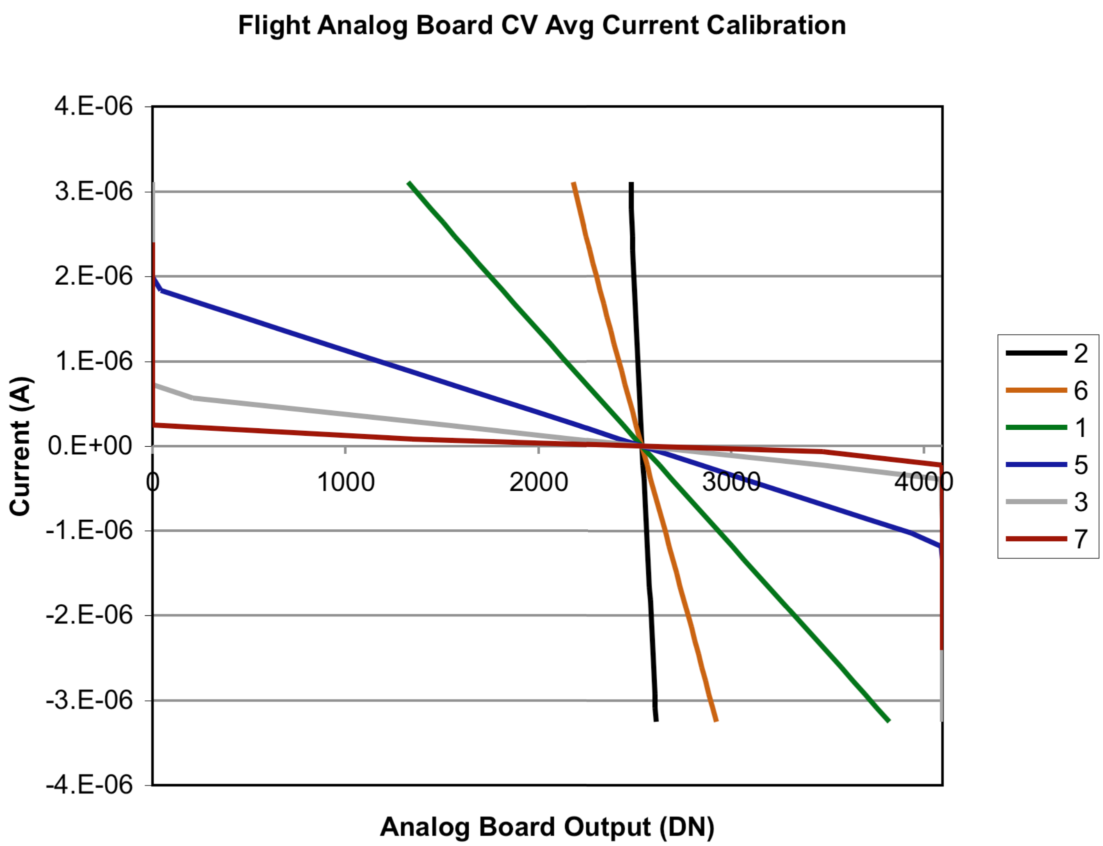


Figure 35. Calibration of DN output to current for the flight analog board (s/n 102) for cyclic voltammetry where I(nA)=m*DN+b.

CV I(nA)=m*DN+b				
Gain Setting	**Slope (m) [nA/DN]**	**Intercept(b) [nA]**	**Slope %RSD**	**Intercept %RSD**
2	-46.08	1.170E+05	0.57	0.57
6	-8.464	2.148E+04	0.09	0.10
1	-2.540	6446	0.03	0.05
5	-0.7376	1866	0.02	0.04
3	-0.2448	616.9	0.03	0.06
7	-0.1037	237.6	0.11	0.15

Table 31. Calibration of DN output to current for the flight analog board (s/n 102) for cyclic voltammetry where I(nA)=m*DN+b.

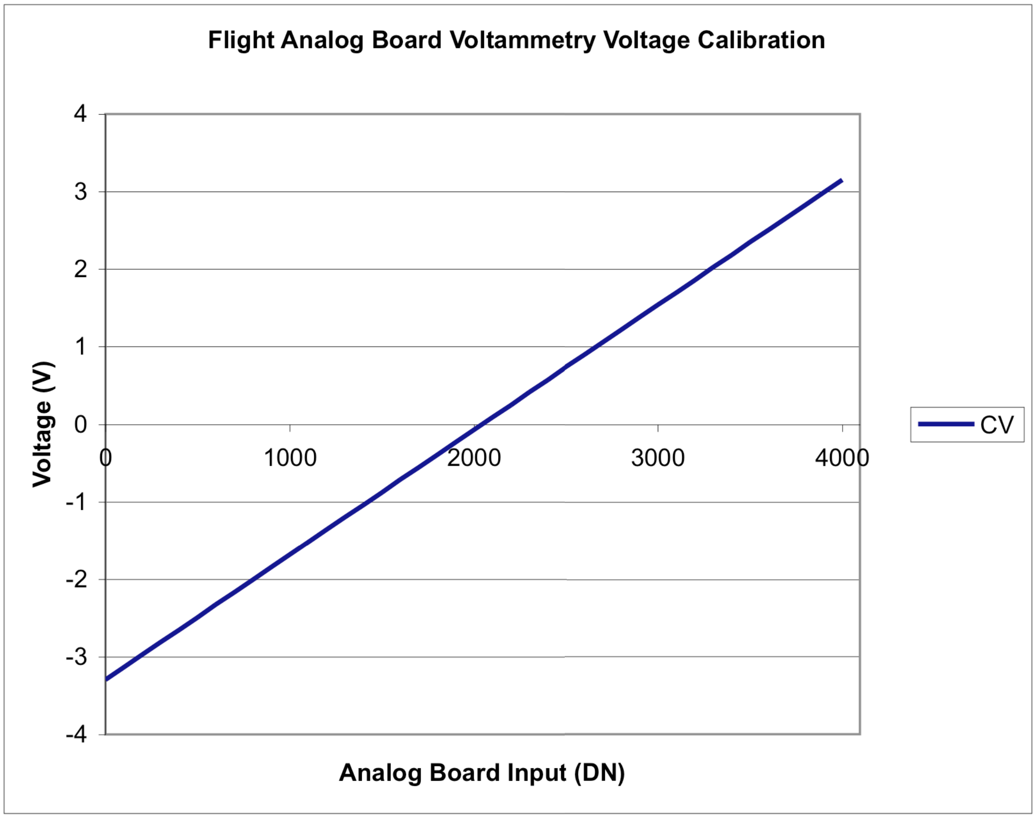


Figure 36. Calibration of DN output to voltage (mV) for the flight analog board (s/n 102) for cyclic voltammetry.

V(mV)=m*DN+b				
Electrode Input	**Slope (m) [mV/DN]**	**Intercept(b) [mV]**	**Slope %RSD**	**Intercept %RSD**
CV	1.612	-3296	0.00	0.01

Table 32. Calibration of DN output to voltage (mV) for the flight analog board (s/n 102) for cyclic voltammetry where V(mV)=m*DN+b.

12.4.3. Anodic Stripping Voltammetry (ASV)

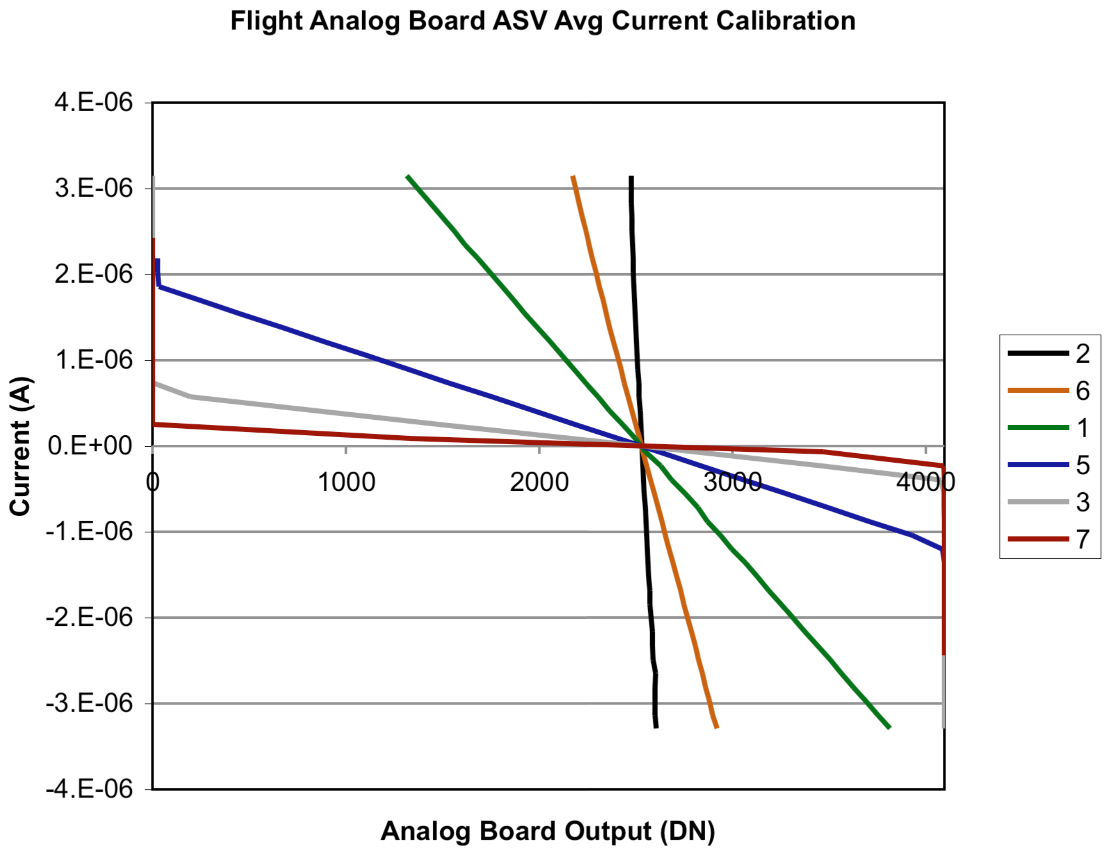


Figure 37. Calibration of DN output to current for the flight analog board (s/n 102) for ASV where I(nA)=m*DN+b.

ASV I(nA)=m*DN+b				
Gain Setting	**Slope (m) [nA/DN]**	**Intercept(b) [nA]**	**Slope %RSD**	**Intercept %RSD**
2	-45.42	1.151E+05	0.66	0.79
6	-8.549	2.164E+04	0.14	0.32
1	-2.569	6504	0.07	0.35
5	-0.7462	1882	0.05	0.30
3	-0.2477	622.6	0.12	0.30
7	-0.1047	239.6	0.25	0.43

Table 33. Calibration of DN output to current for the flight analog board (s/n 102) for ASV where I(nA)=m*DN+b.

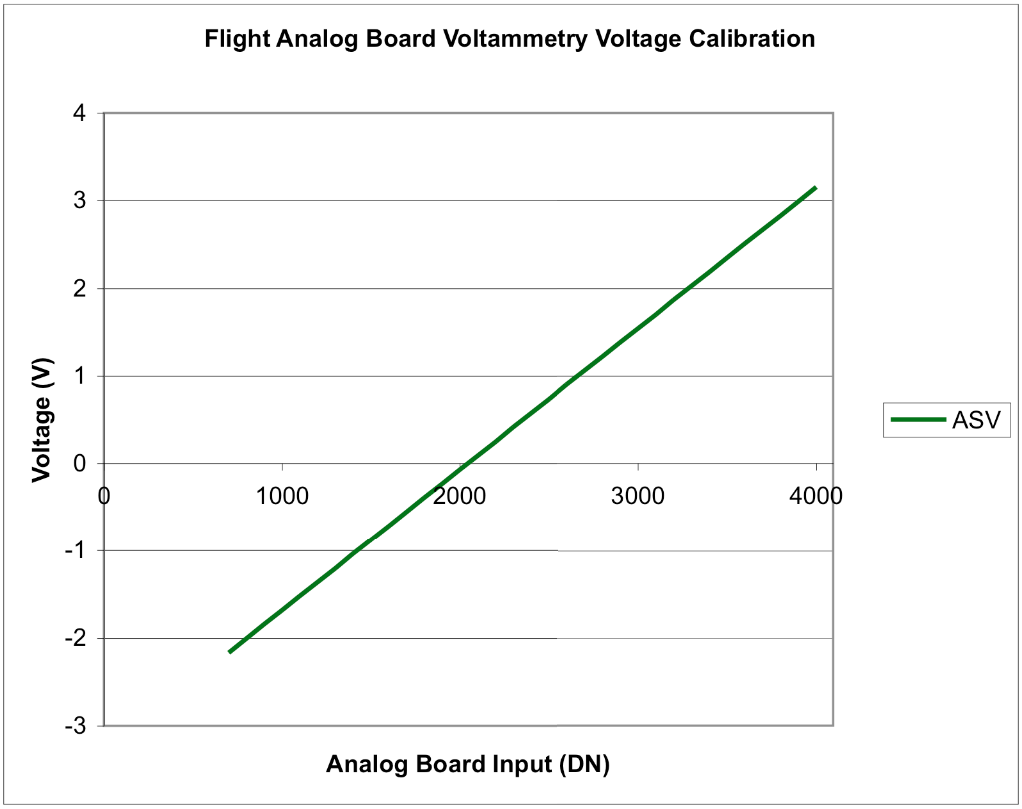


Figure 38. Calibration of DN output to voltage (mV) for the flight analog board (s/n 102) for ASV.

V(mV)=m*DN+b				
Electrode Input	**Slope (m) [mV/DN]**	**Intercept (b) [mV]**	**Slope %RSD**	**Intercept %RSD**
ASV	1.612	-3297	0.01	0.02

Table 34. Calibration of DN output to voltage (mV) for the flight analog board (s/n 102) for ASV where V(mV)=m*DN+b.

13. Appendix A—Acronym List

AA	Actuator Assembly
AB	Analog Board
ADC	Analog to Digital Converter
AFM	Atomic Force Microscope
ATLO	Assembly, Test, and Launch Operations
ARC	[NASA] Ames Research Center
ASV	Anodic Stripping Voltammetry
BCE	Bench Checkout Equipment
CCC	Calibration, Characterization, and Cataloguing
CCD	Charge Coupled Device
CCW	Counter Clockwise
CME	Command and Measurement Electronics
CP	Chronopotentiometry
CV	Cyclic Voltammetry
CW	Clockwise
DC	Direct Current
DHMR	Dry Heat Microbial Reduction
DIW	De-Ionized Water
DM	Dynamic Mode
DMM	Digital Multimeter
DN	Digital Number (or Data Number)
DO (DOX)	Dissolved Oxygen
DOF	Degree of Freedom, Depth of Field
DVM	Digital Voltmeter
EC	Electrical Conductivity
EDL	Entry, Descent, Landing
EGA	Evolved Gas Analyzer
EIDP	End Item Data Package
EM	Engineering Model
EMC	Electromagnetic Compatibility
EMF	Electromotive Force
EMI	Electromagnetic Interference
EQM	Engineering Qualification Model
ERD	Environmental Requirements Document
ESEM	Environmental Scanning Electron Microscope
FBB	Frame Buffer Board
FF	Fill Factor
FPGA	Field Programmable Gate Array
FM	Flight Model
FS	Flight Spare
GSE	Ground Support Equipment
I&T	Integration and Test

IC	Instrument Co-Investigator
ICD	Interface Control Document
IFS	Inner Fill Solution
IM	Instrument Manager
IMT	Institute for Microtechnology
ISE	Ion-Selective Electrode
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
L	Level (as in L3 or L4)
LED	Light Emitting Diode
LM	Lockheed Martin
LS	Limit Switch
MECA	Microscopy, Electrochemistry, & Conductivity Analyzer
MET	Meteorology Experiment
MFSW	MECA Flight Software
MICD	Mechanical Interface Control Document
MSP'01	Mars Surveyor Program 2001 Lander
N/A	Not Applicable
NI	National Instruments
NIST	National Institute of Standards & Technology
OFS	Outer Fill Solution
OM	Optical Microscope
ORP	Oxidation Reduction Potential (redox or eH)
P	Pressure
PACI	Payload and Attitude Control Interface
PC	Personal Computer
PDS	Planetary Data System
PEB	Payload Electronics Box
PEEK	Polyetheretherkeytone
PFR	Problem Failure Report
PIT	Payload Interoperability Testbed
PN	Part Number
PPCF	Programmable Pressure-Controlled Freezer
PVC	Polyvinylchloride
Q	Quarter
RA	Robotic Arm
RAC	Robotic Arm Camera
REF	Reference
RGB	Red, Green, Blue
RH	Relative Humidity
RI	Reverse Imaging
SHB	Sensor Head Board
SEM	Scanning Electron Microscope
SETI	Search for ExtraTerrestrial Intelligence
SL	Servo Loop

SM	Static Mode
SP	Set point
SS	Scan Speed
SSI	Surface Stereo Imager
SWTS	Sample Wheel & Translation Stage
T	Temperature
TB	Testbed
TBD	To Be Determined
TBR	To Be Revised
TCR	Thermal Coefficient of Resistance
TECP	Thermal and Electrical Conductivity Probe
TEGA	Thermal and Evolved Gas Analyzer
TEM	Transmission Electron Microscope
TP	Tip Potential
AUA	University of Arizona
USAF	United States Air Force
UV	Ultraviolet
V&V	Verification and Validation
VA	Vibration Amplitude
WCL	Wet Chemistry Laboratory
WD	Work Days

14. Appendix B—Report on Reagent Dissolution Times by Tufts University

30 April 2007

To: Sam Kounaves (TU), Mike Hecht (JPL), Paula Grunthaner (JPL), and the MECA team.

From: Suzanne M. M. Young, Tufts University

Subject: MECA-WCL Reagents Dissolution Times

Purpose

The purpose of these tasks was to analyze the time it takes to dissolve, thereby delivering reagents to the leach solution, each of the MECA-WCL chemicals loaded in the MECA-WCL crucibles.

The MECA calibrant reagent, in first crucible to be released during MECA-WCL Day-1 experiments on Mars, consists of:

- 5 x 10^{-7} moles of NH_4NO_3
- 5 x 10^{-7} moles of $Mg(NO_3)_2 \bullet 6H_2O$
- 5 x 10^{-7} moles of $CaCl_2$
- 5 x 10^{-7} moles of $NaHCO_3$
- 5 x 10^{-7} moles of KCl
- 5 x 10^{-7} moles of $BaCl_2$

When delivered, this reagent crucible with bring the concentrations for each cation (above) in the MECA-WCL leech solution from 1 x 10^{-5} M to 3 x 10^{-5} M, to serve as a second calibration point for the ISEs in the MECA-WCL flight beaker before a sample of Mars regolith is delivered. These very small amounts of salt are dried onto the walls of the crucible.

The MECA-WCL acid reagent, in the second crucible to be released on during MECA-WCL experiments on Mars (to be released on MECA-WCL Day-2), consists of:

- 0.004g of 2-Nitro-benzoic Acid

When delivered, this acid helps to lower the pH of the solution. On Earth, without any sample in solution, it drops the pH at least as low as 4 within 5 minutes (at 25 ºC. The exact pH change it will induce on Mars cannot be determined prior to the actual MECA-WCL experiments on Mars. This small amount of acid is also dried onto the walls of the crucible.

MECA-WCL also contains three crucibles of:

- 0.1 g of $BaCl_2$ (in each)

These will be delivered on MECA-WCL Day-2 experiments after the acidity enhancement step. This salt is hydraulically pressed into the crucible. The salt level is within 2 mm of the top of the crucible.

This technical report describes the experiments conducted at Tufts University to determine how long each reagents takes to be fully delivered once the crucible is introduced to the leach solution in the MECA-WCL beaker.

Experimental (1) [Crucibles of reagent]

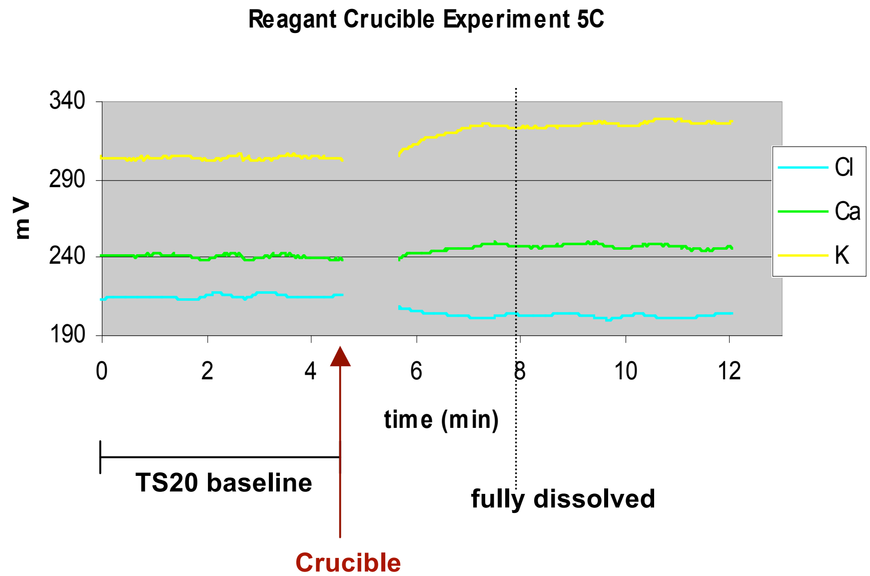
A calibrant reagent crucible was loaded exactly as the flight crucibles were.
25 ml of TS20 is chilled to 5ºC in a 50ml glass beaker.
Measurements with commercial Cl^-, Ca^{2+}, and K^+ ISEs were made of the TS20.The beaker of TS20 was then placed in a vacuum chamber with the calibrant crucible balanced on a vial above the liquid in the beaker.
The vacuum chamber was brought to about 27 Torr (it's minimum). Then whole chamber was shaken until the crucible plunged into the TS20. A stopwatch is started as soon as the crucible falls into the liquid.
The vacuum chamber is vented, the beaker of the TS20 and crucible removed, then measurements with commercial Cl^-, Ca^{2+}, and K^+ ISEs were made again, continually until the reagent level in solution reach equilibrium.
The stop watch is stopped once the ISEs are measuring the solution again.

The stop watch time from the moment the crucible hits the solution until the ISEs are measuring the solution is added to the time from the ISEs measurements until full delivery of the observed ions was reached.

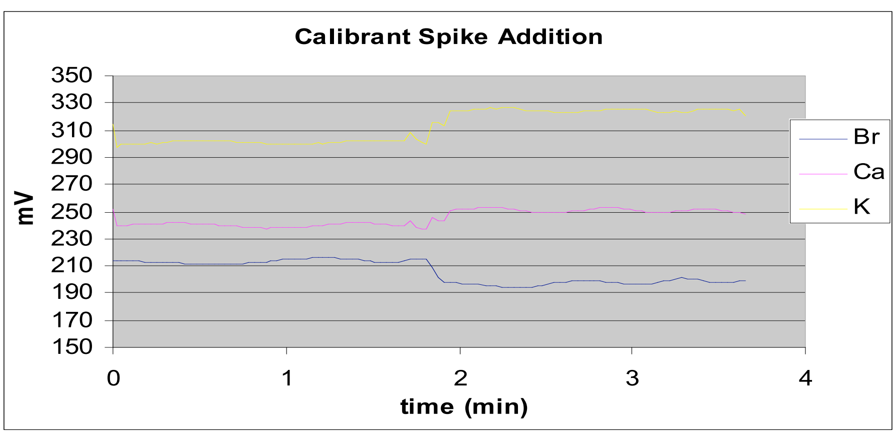
A beaker of TS20 was measured by the same ISEs with a solution injection of the calibrant reagents as well – the exact same amount of calibrant reagents which are dried into the crucibles – in order to compare to confirm complete delivery.

Results (1) [Crucibles of reagent]

This experimentally determined that it takes 3 minutes for the calibrant salts to completely dissolve out of a crucible at 5°C. The graph below shows a baseline TS20 level for Cl^- , Ca^{2+}, and K^+. The gap in data is a result from the procedure of having to drop the crucible into solution at low pressure in a vacuum chamber. When the crucible was introduced into the cell a stopwatch was started for accurate time recording. After being removed from the vacuum chamber, the ISEs could then be used once again. The fully dissolved state was determined after an observed concentration plateau, which also correlated with the expected mV increase from concentration change (approximately 20mV for +1 ions and 10mV for +2 ions). An additional experiment was performed (not shown) simulating a crucible by adding 30uL of the reagent solution (the amount in the crucibles) to TS20, and supported that after 3 minutes the calibrant salts in the crucible are completely dissolved.



Spike Check experiment:



Experimental (2) [Crucibles of acid]

An acid reagent crucible was loaded exactly as the flight crucibles were.
25 ml of TS21 is chilled to 5ºC in a 50ml glass beaker.
Measurements with commercial pH meter were made of the TS21.
The beaker of TS21 was then placed in a vacuum chamber with the acid crucible balanced on a vial above the liquid in the beaker.
The vacuum chamber was brought to about 27 Torr (it's minimum). Then whole chamber was shaken until the crucible plunged into the TS21. A stop watch is started as soon as the crucible falls into the liquid.

The vacuum chamber is vented, the beaker of the TS21 and crucible removed, then measurements with commercial pH meter were made again, continually until the pH level stabilized at 4.
The stop watch is stopped when the pH of 4 is reached.

A beaker of TS21 was measured by the same pH meter with a solution injection of the acid reagent as well – the exact same amount of acid reagent which is dried into the crucibles – in order to compare to confirm complete delivery.

Results (2) [Crucibles of acid]

It was experimentally determined that it takes less than 5 minutes for the 2-nitrobenzoic acid to dissolve from the crucible at 5°C to reach pH 4. All pH values were recorded manually (notebook 3 of Casey A. Cable pgs. 27-28 on 10/30/06, pgs. 40-41 on 11/29/06) using a Thermo Orion pH electrode with simulated stirring of the Starsis top unit.

Experimental (3) [Crucibles of barium chloride]

A barium reagent crucible was packed exactly as the flight crucibles were.
25 ml of TS21 plus acid is chilled to 5ºC in a 50ml glass beaker.
Measurements with a commercial Cl^- ISE were made of this solution.
The beaker of solution was then placed in a vacuum chamber with the barium crucible balanced on a vial above the liquid in the beaker.
The vacuum chamber was brought to about 27 Torr (it's minimum). Then whole chamber was shaken until the crucible plunged into the solution.
The vacuum chamber is vented, the beaker of the solution and crucible removed, then measurements with Cl^- ISE were made again, continually until the barium level in solution reach equilibrium.

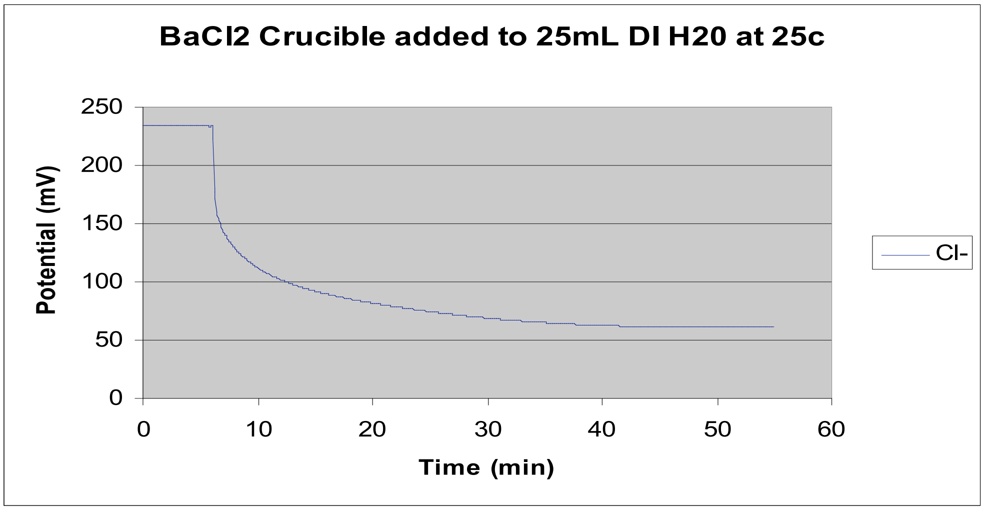
A beaker of TS21 plus acid was measured by the same ISE with a weighted solid $BaCl_2$ scoop delivered as well – the exact same amount of $BaCl_2$ which is packed into the crucibles – in order to compare to confirm complete delivery.

This same procedure was performed at room temperature (25 degrees) as well.

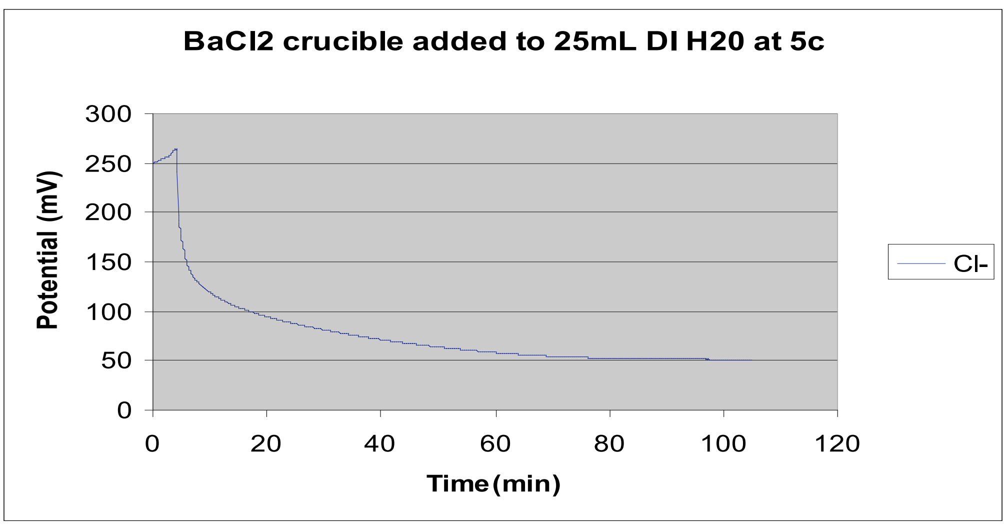
Results (3) [Crucibles of barium chloride]

At colder temperatures cause the $BaCl_2$ to dissolve out of the crucible slower,

and at 5c it takes approximately 80 minutes for the $BaCl_2$ to completely dissolve out .



At 25c it will take approximately 30-50 minutes for the $BaCl_2$ to dissolve out of the crucible.



Conclusion

Even at cold operating temperatures, both the calibrant and acid reagents are dissolved out f their crucible and delivered to the solution in less than 5 minutes.

However, the temperature makes a large difference for the delivery of the barium chloride to the solutions. At 5 ºC, it takes well over an hour to deliver the barium. But at 20 ºC, it would be possible to deliver the barium in less than an hour.

It is recommended by Tufts that we warm the beaker to at least 20 ºC before beginning the barium-sulfate titration experiments on MECA-WCL Day 2.

Note: As soon as the barium ions are in solution with any sulfate, the precipitation is immediate. The time limiting factor of the measurement or experimental conditions is the time it takes the salt to be dissolved out of the crucible.

15. Appendix C—Summary of Beaker ISE Calibration Data

15.1. Summary of Thermo "After Integration" Calibration Data (Aug 2006) for Flight Units 229918-014, -018, -020, -022

014

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	78.0	-4.8	-117.3	-2.3	-122.4
3.00E-05	-4.5	90.5	8.2	-92.0	11.4	-93.4
1.00E-04	-4.0	105.2	22.8	-61.1	25.3	-66.2
1.00E-03	-3.0	132.8	49.7	-3.0	53.0	-6.0
1.00E-02	-2.0	154.4	70.7	51.1	75.4	45.1

Conc. Na	Log(Conc)	Na
1.00E-05	-5.0	-66.7
3.00E-05	-4.5	-45.3
1.10E-04	-4.0	-17.0
1.01E-03	-3.0	36.0
1.00E-02	-2.0	89.1

Conc. Cl	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	284.4	284.9	187.8	263.0
1.50E-04	-3.8	260.7	261.1	169.9	246.1
6.00E-04	-3.2	228.7	228.7	156.4	222.3
6.00E-03	-2.2	172.9	173.8	115.8	180.0
6.00E-02	-1.2	120.0	121.2	60.3	126.4

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	-2.3	600	2	8.63E-01	8.6E-06	-5.1	-4.8	300	1	9.6E-01	9.6E-06	-5.0	-117.3
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	11.4	600	2	8.51E-01	2.6E-05	-4.6	8.2	300	1	9.6E-01	2.9E-05	-4.5	-92.0
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	25.3	600	2	8.17E-01	8.2E-05	-4.1	22.8	300	1	9.5E-01	9.5E-05	-4.0	-61.1
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	53.0	600	2	6.46E-01	6.5E-04	-3.2	49.7	300	1	8.9E-01	8.9E-04	-3.1	-3.0
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	75.4	600	2	3.79E-01	3.8E-03	-2.4	70.7	300	1	7.4E-01	7.4E-03	-2.1	51.1

018

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	65.0	-8.4	-120.7	-19.5	-119.9
3.00E-05	-4.5	78.6	6.0	-96.6	-6.5	-93.0
1.00E-04	-4.0	93.9	20.6	-65.3	7.3	-61.7
1.00E-03	-3.0	119.6	47.5	-9.4	33.6	-4.6
1.00E-02	-2.0	141.0	67.7	44.0	55.6	44.6

Conc	Log(Conc)	Na
1.00E-05	-5.0	-99.4
3.00E-05	-4.5	-78.6
1.10E-04	-4.0	-50.8
1.01E-03	-3.0	0.8
1.00E-02	-2.0	53.1

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	274.4	274.4	179.3	264.5
1.50E-04	-3.8	255.7	258.1	155.4	246.2
6.00E-04	-3.2	225.0	226.0	142.2	221.7
6.00E-03	-2.2	169.9	171.1	106.9	174.0
6.00E-02	-1.2	114.4	115.2	53.3	120.0

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	-19.5	600	2	8.63E-01	8.6E-06	-5.1	-8.4	300	1	9.6E-01	9.6E-06	-5.0	-120.7
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	-6.5	600	2	8.51E-01	2.6E-05	-4.6	6.0	300	1	9.6E-01	2.9E-05	-4.5	-96.6
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	7.3	600	2	8.17E-01	8.2E-05	-4.1	20.6	300	1	9.5E-01	9.5E-05	-4.0	-65.3
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	33.6	600	2	6.46E-01	6.5E-04	-3.2	47.5	300	1	8.9E-01	8.9E-04	-3.1	-9.4
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	55.6	600	2	3.79E-01	3.8E-03	-2.4	67.7	300	1	7.4E-01	7.4E-03	-2.1	44.0

020

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	68.3	-5.3	-122.6	-7.8	-110.3
3.00E-05	-4.5	82.6	9.8	-94.6	4.8	-83.7
1.00E-04	-4.0	98.3	23.5	-65.0	19.9	-54.0
1.00E-03	-3.0	125.5	51.5	-6.4	47.3	3.7
1.00E-02	-2.0	146.1	72.0	46.2	68.7	59.0

Conc	Log(Conc)	Na
1.00E-05	-5.0	-100.2
3.00E-05	-4.5	-78.6
1.10E-04	-4.0	-49.5
1.01E-03	-3.0	3.8
1.00E-02	-2.0	56.1

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	282.2	282.4	205.9	238.7
1.50E-04	-3.8	264.1	262.6	186.2	222.8
6.00E-04	-3.2	229.3	230.3	163.1	209.7
6.00E-03	-2.2	174.8	176.4	120.8	170.5
6.00E-02	-1.2	120.5	121.2	67.6	119.2

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	-7.8	600	2	8.63E-01	8.6E-06	-5.1	-5.3	300	1	9.6E-01	9.6E-06	-5.0	-122.6
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	4.8	600	2	8.51E-01	2.6E-05	-4.6	9.8	300	1	9.6E-01	2.9E-05	-4.5	-94.6
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	19.9	600	2	8.17E-01	8.2E-05	-4.1	23.5	300	1	9.5E-01	9.5E-05	-4.0	-65.0
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	47.3	600	2	6.46E-01	6.5E-04	-3.2	51.5	300	1	8.9E-01	8.9E-04	-3.1	-6.4
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	68.7	600	2	3.79E-01	3.8E-03	-2.4	72.0	300	1	7.4E-01	7.4E-03	-2.1	46.2

022

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	75.9	-6.6	-119.1	-6.4	-110.7
3.00E-05	-4.5	88.9	8.2	-92.0	7.7	-83.7
1.00E-04	-4.0	104.1	21.3	-62.5	21.5	-53.2
1.00E-03	-3.0	131.1	48.5	-4.5	48.5	5.4
1.00E-02	-2.0	152.6	68.9	49.6	71.2	56.2

Conc	Log(Conc)	Na
1.00E-05	-5.0	-93.5
3.00E-05	-4.5	-71.6
1.10E-04	-4.0	-44.0
1.01E-03	-3.0	9.5
1.00E-02	-2.0	60.8

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	280.3	281.5	193.8	265.3
1.50E-04	-3.8	260.2	260.1	157.0	250.2
6.00E-04	-3.2	227.5	229.3	140.9	222.0
6.00E-03	-2.2	174.9	176.0	105.2	172.2
6.00E-02	-1.2	120.5	120.8	50.0	120.4

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	-6.4	600	2	8.63E-01	8.6E-06	-5.1	-6.6	300	1	9.6E-01	9.6E-06	-5.0	-119.1
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	7.7	600	2	8.51E-01	2.6E-05	-4.6	8.2	300	1	9.6E-01	2.9E-05	-4.5	-92.0
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	21.5	600	2	8.17E-01	8.2E-05	-4.1	21.3	300	1	9.5E-01	9.5E-05	-4.0	-62.5
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	48.5	600	2	6.46E-01	6.5E-04	-3.2	48.5	300	1	8.9E-01	8.9E-04	-3.1	-4.5
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	71.2	600	2	3.79E-01	3.8E-03	-2.4	68.9	300	1	7.4E-01	7.4E-03	-2.1	49.6

014

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc. Li	Log(Conc)	Li(2)	Conc. NO3	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	23.7	7.7	278.1	1.00E-03	-3.0	0.6	1.03E-03	-3.0	239.3	571.1	-58.4	77
3.00E-05	-4.5	5.9	-12.4	281.9	1.00E-03	-3.0	1.2	1.09E-03	-3.0	238.3	507.5	-59.0	91
1.00E-05	-5.0	18.7	1.4	285.4	1.00E-03	-3.0	0.0	1.30E-03	-2.9	234.4	489.8	-58.8	144
1.00E-05	-5.0	35.2	18.2	297.8	1.00E-03	-3.0	0.9	4.00E-03	-2.4	207.7	493.1	-58.6	750
1.00E-05	-5.0	43.4	26.2	296.3	1.00E-03	-3.0	1.2	3.10E-02	-1.5	160.7	486.9	-57.0	5281

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc. Na	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	78.0	250	1	9.6E-01	9.6E-06	-5.0	-122.4	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-66.7
500	2	8.5E-01	2.5E-05	-4.6	90.5	250	1	9.6E-01	2.9E-05	-4.5	-93.4	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-45.3
500	2	8.1E-01	8.1E-05	-4.1	105.2	250	1	9.5E-01	9.5E-05	-4.0	-66.2	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-17.0
500	2	6.4E-01	6.4E-04	-3.2	132.8	250	1	8.8E-01	8.8E-04	-3.1	-6.0	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	36.0
500	2	3.5E-01	3.5E-03	-2.5	154.4	250	1	7.3E-01	7.3E-03	-2.1	45.1	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	89.1

018

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(2)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	-1.8	20.4	185.6	1.00E-03	-3.0	-2.8	1.03E-03	-3.0	235.4	341.7	-36.8	79
3.00E-05	-4.5	-18.1	4.8	182.4	1.00E-03	-3.0	-2.3	1.09E-03	-3.0	235.1	334.4	-37.9	93
1.00E-05	-5.0	4.9	26.8	194.9	1.00E-03	-3.0	-1.7	1.30E-03	-2.9	231.0	352.4	-37.9	148
1.00E-05	-5.0	9.9	32.7	203.1	1.00E-03	-3.0	-3.1	4.00E-03	-2.4	204.0	350.1	-37.7	785
1.00E-05	-5.0	16.6	39.3	202.2	1.00E-03	-3.0	-3.1	3.10E-02	-1.5	156.3	338.2	-36.9	5534

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	65.0	250	1	9.6E-01	9.6E-06	-5.0	-119.9	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-99.4
500	2	8.5E-01	2.5E-05	-4.6	78.6	250	1	9.6E-01	2.9E-05	-4.5	-93.0	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-78.6
500	2	8.1E-01	8.1E-05	-4.1	93.9	250	1	9.5E-01	9.5E-05	-4.0	-61.7	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-50.8
500	2	6.4E-01	6.4E-04	-3.2	119.6	250	1	8.8E-01	8.8E-04	-3.1	-4.6	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	0.8
500	2	3.5E-01	3.5E-03	-2.5	141.0	250	1	7.3E-01	7.3E-03	-2.1	44.6	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	53.1

020

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(2)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	20.6	23.0	301.9	1.00E-03	-3.0	-0.9	1.03E-03	-3.0	244.3	488.2	-41.9	80
3.00E-05	-4.5	8.7	10.4	300.4	1.00E-03	-3.0	-0.2	1.09E-03	-3.0	244.9	459.8	-41.2	94
1.00E-05	-5.0	30.1	32.2	311.3	1.00E-03	-3.0	-0.2	1.30E-03	-2.9	239.7	471.2	-40.9	151
1.00E-05	-5.0	36.1	38.8	321.5	1.00E-03	-3.0	-0.1	4.00E-03	-2.4	213.5	472.7	-40.0	811
1.00E-05	-5.0	43.2	45.4	324.0	1.00E-03	-3.0	-0.3	3.10E-02	-1.5	165.7	472.4	-38.3	5871

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	68.3	250	1	9.6E-01	9.6E-06	-5.0	-110.3	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-100.2
500	2	8.5E-01	2.5E-05	-4.6	82.6	250	1	9.6E-01	2.9E-05	-4.5	-83.7	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-78.6
500	2	8.1E-01	8.1E-05	-4.1	98.3	250	1	9.5E-01	9.5E-05	-4.0	-54.0	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-49.5
500	2	6.4E-01	6.4E-04	-3.2	125.5	250	1	8.8E-01	8.8E-04	-3.1	3.7	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	3.8
500	2	3.5E-01	3.5E-03	-2.5	146.1	250	1	7.3E-01	7.3E-03	-2.1	59.0	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	56.1

022

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(2)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	29.5	3.5	324.9	1.00E-03	-3.0	0.8	1.03E-03	-3.0	246.2	534.9	-11.5	78
3.00E-05	-4.5	16.2	-10.5	323.4	1.00E-03	-3.0	1.1	1.09E-03	-3.0	245.5	484.0	-11.1	91
1.00E-05	-5.0	36.1	10.0	332.0	1.00E-03	-3.0	0.8	1.30E-03	-2.9	239.9	471.3	-12.3	145
1.00E-05	-5.0	43.2	17.0	339.2	1.00E-03	-3.0	0.3	4.00E-03	-2.4	213.7	464.8	-12.9	750
1.00E-05	-5.0	51.2	24.7	339.5	1.00E-03	-3.0	-0.3	3.10E-02	-1.5	166.0	453.9	-12.6	4778

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	75.9	250	1	9.6E-01	9.6E-06	-5.0	-110.7	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-93.5
500	2	8.5E-01	2.5E-05	-4.6	88.9	250	1	9.6E-01	2.9E-05	-4.5	-83.7	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-71.6
500	2	8.1E-01	8.1E-05	-4.1	104.1	250	1	9.5E-01	9.5E-05	-4.0	-53.2	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-44.0
500	2	6.4E-01	6.4E-04	-3.2	131.1	250	1	8.8E-01	8.8E-04	-3.1	5.4	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	9.5
500	2	3.5E-01	3.5E-03	-2.5	152.6	250	1	7.3E-01	7.3E-03	-2.1	56.2	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	60.8

15.2. Summary of JPL "As Received" Calibration Data (Aug 2006) for Flight Units 229918-014, -018, -020, -022

014

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	77.1	-3.9	-102.1	3.6	-113.6
3.00E-05	-4.5	89.3	9.2	-89.9	13.6	-90.4
1.00E-04	-4.0	104.5	23.9	-59.7	29.1	-60.3
1.00E-03	-3.0	132.8	51.1	-1.0	55.8	-1.7
1.00E-02	-2.0	152.8	70.5	52.4	76.7	50.1

Conc	Log(Conc)	Na
1.00E-05	-5.0	-57.2
3.00E-05	-4.5	-40.4
1.10E-04	-4.0	-12.7
1.01E-03	-3.0	41.6
1.00E-02	-2.0	93.3

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	279.2	279.6	175.8	260.2
1.50E-04	-3.8	261.6	262.7	162.4	245.3
6.00E-04	-3.2	229.9	230.3	151.3	222.2
6.00E-03	-2.2	174.1	175.7	115.6	175.2
6.00E-02	-1.2	118.7	118.8	59.4	122.1

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	3.6	600	2	8.63E-01	8.6E-06	-5.1	-3.9	300	1	9.6E-01	9.6E-06	-5.0	-102.1
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	13.6	600	2	8.51E-01	2.6E-05	-4.6	9.2	300	1	9.6E-01	2.9E-05	-4.5	-89.9
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	29.1	600	2	8.17E-01	8.2E-05	-4.1	23.9	300	1	9.5E-01	9.5E-05	-4.0	-59.7
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	55.8	600	2	6.46E-01	6.5E-04	-3.2	51.1	300	1	8.9E-01	8.9E-04	-3.1	-1.0
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	76.7	600	2	3.79E-01	3.8E-03	-2.4	70.5	300	1	7.4E-01	7.4E-03	-2.1	52.4

018

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	65.9	-3.4	-115.8	-12.5	-114.4
3.00E-05	-4.5	79.5	8.9	-101.3	0.4	-87.3
1.00E-04	-4.0	95.5	25.1	-70.1	15.1	-55.7
1.00E-03	-3.0	122.5	51.1	-11.9	41.3	2.9
1.00E-02	-2.0	142.3	69.7	40.4	60.4	55.3

Conc	Log(Conc)	Na
1.00E-05	-5.0	-95.6
3.00E-05	-4.5	-77.2
1.10E-04	-4.0	-49.8
1.01E-03	-3.0	3.7
1.00E-02	-2.0	54.3

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	272.6	275.6	170.6	262.0
1.50E-04	-3.8	258.0	259.5	160.6	247.1
6.00E-04	-3.2	228.0	228.5	146.3	223.9
6.00E-03	-2.2	172.8	173.0	118.9	177.6
6.00E-02	-1.2	116.6	116.7	61.1	121.0

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	-12.5	600	2	8.63E-01	8.6E-06	-5.1	-3.4	300	1	9.6E-01	9.6E-06	-5.0	-115.8
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	0.4	600	2	8.51E-01	2.6E-05	-4.6	8.9	300	1	9.6E-01	2.9E-05	-4.5	-101.3
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	15.1	600	2	8.17E-01	8.2E-05	-4.1	25.1	300	1	9.5E-01	9.5E-05	-4.0	-70.1
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	41.3	600	2	6.46E-01	6.5E-04	-3.2	51.1	300	1	8.9E-01	8.9E-04	-3.1	-11.9
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	60.4	600	2	3.79E-01	3.8E-03	-2.4	69.7	300	1	7.4E-01	7.4E-03	-2.1	40.4

020

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	71.8	-2.3	-108.9	-5.1	-107.1
3.00E-05	-4.5	85.0	9.3	-95.6	7.8	-79.7
1.00E-04	-4.0	99.5	23.8	-65.0	21.8	-48.4
1.00E-03	-3.0	126.6	50.3	-7.0	48.4	9.5
1.00E-02	-2.0	146.4	69.4	45.9	69.0	63.6

Conc	Log(Conc)	Na
1.00E-05	-5.0	-92.1
3.00E-05	-4.5	-75.0
1.10E-04	-4.0	-46.2
1.01E-03	-3.0	6.0
1.00E-02	-2.0	57.9

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	280.1	280.2	188.0	233.2
1.50E-04	-3.8	261.3	262.0	176.1	219.5
6.00E-04	-3.2	230.7	230.9	161.4	208.7
6.00E-03	-2.2	174.2	174.9	121.5	167.7
6.00E-02	-1.2	118.6	119.3	67.7	116.7

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	-5.1	600	2	8.63E-01	8.6E-06	-5.1	-2.3	300	1	9.6E-01	9.6E-06	-5.0	-108.9
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	7.8	600	2	8.51E-01	2.6E-05	-4.6	9.3	300	1	9.6E-01	2.9E-05	-4.5	-95.6
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	21.8	600	2	8.17E-01	8.2E-05	-4.1	23.8	300	1	9.5E-01	9.5E-05	-4.0	-65.0
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	48.4	600	2	6.46E-01	6.5E-04	-3.2	50.3	300	1	8.9E-01	8.9E-04	-3.1	-7.0
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	69.0	600	2	3.79E-01	3.8E-03	-2.4	69.4	300	1	7.4E-01	7.4E-03	-2.1	45.9

022

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	73.9	-6.1	-107.0	-2.7	-106.2
3.00E-05	-4.5	88.5	8.0	-93.8	9.9	-77.1
1.00E-04	-4.0	104.7	23.2	-62.2	25.9	-45.7
1.00E-03	-3.0	131.8	49.9	-4.0	52.0	11.3
1.00E-02	-2.0	152.9	70.4	49.5	74.2	66.7

Conc	Log(Conc)	Na
1.00E-05	-5.0	-87.9
3.00E-05	-4.5	-69.0
1.10E-04	-4.0	-40.7
1.01E-03	-3.0	12.1
1.00E-02	-2.0	64.8

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	279.8	279.1	154.6	262.9
1.50E-04	-3.8	260.5	262.3	139.9	248.6
6.00E-04	-3.2	229.8	231.0	142.3	224.6
6.00E-03	-2.2	175.7	176.4	108.8	172.5
6.00E-02	-1.2	120.5	120.8	52.9	118.9

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	-2.7	600	2	8.63E-01	8.6E-06	-5.1	-6.1	300	1	9.6E-01	9.6E-06	-5.0	-107.0
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	9.9	600	2	8.51E-01	2.6E-05	-4.6	8.0	300	1	9.6E-01	2.9E-05	-4.5	-93.8
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	25.9	600	2	8.17E-01	8.2E-05	-4.1	23.2	300	1	9.5E-01	9.5E-05	-4.0	-62.2
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	52.0	600	2	6.46E-01	6.5E-04	-3.2	49.9	300	1	8.9E-01	8.9E-04	-3.1	-4.0
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	74.2	600	2	3.79E-01	3.8E-03	-2.4	70.4	300	1	7.4E-01	7.4E-03	-2.1	49.5

014

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(1)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	30.2	13.9	293.1	1.00E-03	-3.0	0.7	1.03E-03	-3.0	240.7	303.3	-62.1	78
3.00E-05	-4.5	7.6	-9.9	285.6	1.00E-03	-3.0	0.3	1.09E-03	-3.0	240.0	281.9	-63.1	92
1.00E-05	-5.0	31.0	12.7	288.5	1.00E-03	-3.0	1.4	1.30E-03	-2.9	235.5	307.0	-63.3	146
1.00E-05	-5.0	36.7	18.8	293.7	1.00E-03	-3.0	1.9	4.00E-03	-2.4	208.9	319.1	-63.2	747
1.00E-05	-5.0	39.4	21.6	287.4	1.00E-03	-3.0	1.3	3.10E-02	-1.5	159.7	325.0	-62.9	5342

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	-113.6306	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	77.1	250	1	9.6E-01	9.6E-06	-5.0	-90.4	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-57.2
500	2	8.5E-01	2.5E-05	-4.6	89.3	250	1	9.6E-01	2.9E-05	-4.5	-60.3	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-40.4
500	2	8.1E-01	8.1E-05	-4.1	104.5	250	1	9.5E-01	9.5E-05	-4.0	-1.7	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-12.7
500	2	6.4E-01	6.4E-04	-3.2	132.8	250	1	8.8E-01	8.8E-04	-3.1	50.1	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	41.6
500	2	3.5E-01	3.5E-03	-2.5	152.8	250	1	7.3E-01	7.3E-03	-2.1	58.1	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	93.3

018

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(1)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	0.7	24.2	184.6	1.00E-03	-3.0	0.0	1.03E-03	-3.0	239.2	321.8	-47.1	81
3.00E-05	-4.5	-22.2	1.3	176.8	1.00E-03	-3.0	0.3	1.09E-03	-3.0	238.0	303.8	-48.8	95
1.00E-05	-5.0	4.3	27.4	192.3	1.00E-03	-3.0	0.7	1.30E-03	-2.9	234.6	333.3	-49.6	151
1.00E-05	-5.0	9.3	32.3	199.5	1.00E-03	-3.0	0.7	4.00E-03	-2.4	207.7	337.5	-49.4	787
1.00E-05	-5.0	13.2	36.4	199.9	1.00E-03	-3.0	1.2	3.10E-02	-1.5	158.0	335.0	-49.2	5599

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	65.9	250	1	9.6E-01	9.6E-06	-5.0	-114.4	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-95.6
500	2	8.5E-01	2.5E-05	-4.6	79.5	250	1	9.6E-01	2.9E-05	-4.5	-87.3	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-77.2
500	2	8.1E-01	8.1E-05	-4.1	95.5	250	1	9.5E-01	9.5E-05	-4.0	-55.7	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-49.8
500	2	6.4E-01	6.4E-04	-3.2	122.5	250	1	8.8E-01	8.8E-04	-3.1	2.9	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	3.7
500	2	3.5E-01	3.5E-03	-2.5	142.3	250	1	7.3E-01	7.3E-03	-2.1	55.3	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	54.3

020

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(1)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	24.8	27.6	285.1	1.00E-03	-3.0	2.5	1.03E-03	-3.0	244.2	328.4	-49.5	82
3.00E-05	-4.5	2.3	5.5	281.5	1.00E-03	-3.0	2.5	1.09E-03	-3.0	243.0	304.1	-50.3	97
1.00E-05	-5.0	28.1	30.2	292.3	1.00E-03	-3.0	2.5	1.30E-03	-2.9	239.1	329.3	-51.1	154
1.00E-05	-5.0	32.5	35.1	303.5	1.00E-03	-3.0	2.8	4.00E-03	-2.4	211.5	340.1	-51.0	820
1.00E-05	-5.0	36.1	39.7	304.0	1.00E-03	-3.0	2.4	3.10E-02	-1.5	162.1	343.8	-50.7	5985

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	71.8	250	1	9.6E-01	9.6E-06	-5.0	-107.1	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-92.1
500	2	8.5E-01	2.5E-05	-4.6	85.0	250	1	9.6E-01	2.9E-05	-4.5	-79.7	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-75.0
500	2	8.1E-01	8.1E-05	-4.1	99.5	250	1	9.5E-01	9.5E-05	-4.0	-48.4	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-46.2
500	2	6.4E-01	6.4E-04	-3.2	126.6	250	1	8.8E-01	8.8E-04	-3.1	9.5	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	6.0
500	2	3.5E-01	3.5E-03	-2.5	146.4	250	1	7.3E-01	7.3E-03	-2.1	63.6	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	57.9

022

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(1)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	34.6	9.4	305.5	1.00E-03	-3.0	0.5	1.03E-03	-3.0	245.6	362.7	169.1	81
3.00E-05	-4.5	11.7	-13.9	296.9	1.00E-03	-3.0	2.1	1.09E-03	-3.0	246.0	335.6	165.2	94
1.00E-05	-5.0	56.4	30.6	311.2	1.00E-03	-3.0	2.4	1.30E-03	-2.9	241.1	369.2	162.1	149
1.00E-05	-5.0	98.8	72.5	354.2	1.00E-03	-3.0	2.0	4.00E-03	-2.4	214.4	394.2	159.2	751
1.00E-05	-5.0	88.7	62.7	345.0	1.00E-03	-3.0	4.6	3.10E-02	-1.5	166.1	377.6	158.2	4721

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	73.9	250	1	9.6E-01	9.6E-06	-5.0	-106.2	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-87.9
500	2	8.5E-01	2.5E-05	-4.6	88.5	250	1	9.6E-01	2.9E-05	-4.5	-77.1	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-69.0
500	2	8.1E-01	8.1E-05	-4.1	104.7	250	1	9.5E-01	9.5E-05	-4.0	-45.7	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-40.7
500	2	6.4E-01	6.4E-04	-3.2	131.8	250	1	8.8E-01	8.8E-04	-3.1	11.3	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	12.1
500	2	3.5E-01	3.5E-03	-2.5	152.9	250	1	7.3E-01	7.3E-03	-2.1	66.7	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	64.8

15.3. Summary of JPL "After Protoflight Testing" Calibration Data (Dec 2006) for Flight Units 229918-014, -018, -020, -022

014

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	75.1	-1.5	-114.8	1.1	-122.4
3.00E-05	-4.5	88.8	11.4	-90.1	13.9	-92.5
1.00E-04	-4.0	104.3	26.7	-58.9	28.8	-60.8
1.00E-03	-3.0	131.8	53.7	-1.5	54.8	-2.3
1.00E-02	-2.0	151.8	71.6	51.4	75.2	50.7

Conc	Log(Conc)	Na
1.00E-05	-5.0	-54.4
3.00E-05	-4.5	-35.2
1.10E-04	-4.0	-6.4
1.01E-03	-3.0	46.9
1.00E-02	-2.0	98.0

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	280.9	281.5	92.5	257.0
1.50E-04	-3.8	260.3	261.7	94.1	243.0
6.00E-04	-3.2	228.7	230.6	100.7	221.3
6.00E-03	-2.2	174.4	175.8	104.5	171.9
6.00E-02	-1.2	117.0	119.0	89.1	115.6

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	1.1	600	2	8.63E-01	8.6E-06	-5.1	-1.5	300	1	9.6E-01	9.6E-06	-5.0	-114.8
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	13.9	600	2	8.51E-01	2.6E-05	-4.6	11.4	300	1	9.6E-01	2.9E-05	-4.5	-90.1
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	28.8	600	2	8.17E-01	8.2E-05	-4.1	26.7	300	1	9.5E-01	9.5E-05	-4.0	-58.9
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	54.8	600	2	6.46E-01	6.5E-04	-3.2	53.7	300	1	8.9E-01	8.9E-04	-3.1	-1.5
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	75.2	600	2	3.79E-01	3.8E-03	-2.4	71.6	300	1	7.4E-01	7.4E-03	-2.1	51.4

018

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	64.9	-0.9	-121.3	-8.6	-127.9
3.00E-05	-4.5	78.1	11.6	-95.0	2.6	-95.3
1.00E-04	-4.0	93.6	26.7	-63.7	16.5	-64.4
1.00E-03	-3.0	120.8	53.9	-5.8	42.1	-5.1
1.00E-02	-2.0	140.2	72.6	46.8	61.9	46.9

Conc	Log(Conc)	Na
1.00E-05	-5.0	-88.6
3.00E-05	-4.5	-69.9
1.10E-04	-4.0	-41.8
1.01E-03	-3.0	9.8
1.00E-02	-2.0	61.8

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	278.3	278.3	122.2	251.5
1.50E-04	-3.8	258.4	257.1	121.9	239.1
6.00E-04	-3.2	228.6	229.2	125.7	219.4
6.00E-03	-2.2	173.8	174.6	103.6	176.9
6.00E-02	-1.2	117.2	118.3	58.6	123.4

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	-8.6	600	2	8.63E-01	8.6E-06	-5.1	-0.9	300	1	9.6E-01	9.6E-06	-5.0	-121.3
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	2.6	600	2	8.51E-01	2.6E-05	-4.6	11.6	300	1	9.6E-01	2.9E-05	-4.5	-95.0
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	16.5	600	2	8.17E-01	8.2E-05	-4.1	26.7	300	1	9.5E-01	9.5E-05	-4.0	-63.7
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	42.1	600	2	6.46E-01	6.5E-04	-3.2	53.9	300	1	8.9E-01	8.9E-04	-3.1	-5.8
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	61.9	600	2	3.79E-01	3.8E-03	-2.4	72.6	300	1	7.4E-01	7.4E-03	-2.1	46.8

020

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	66.7	-1.8	-121.3	-5.0	-116.9
3.00E-05	-4.5	80.3	11.0	-95.5	7.1	-87.4
1.00E-04	-4.0	95.3	25.8	-64.9	20.8	-55.8
1.00E-03	-3.0	124.0	53.1	-6.5	47.7	3.4
1.00E-02	-2.0	144.2	72.3	46.6	68.5	56.8

Conc	Log(Conc)	Na
1.00E-05	-5.0	-87.6
3.00E-05	-4.5	-68.6
1.10E-04	-4.0	-41.1
1.01E-03	-3.0	11.8
1.00E-02	-2.0	62.4

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	279.4	281.4	81.6	229.2
1.50E-04	-3.8	257.4	261.3	93.4	219.9
6.00E-04	-3.2	228.1	229.5	109.8	206.0
6.00E-03	-2.2	174.9	176.6	98.4	165.7
6.00E-02	-1.2	119.2	120.1	58.0	112.9

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	-5.0	600	2	8.63E-01	8.6E-06	-5.1	-1.8	300	1	9.6E-01	9.6E-06	-5.0	-121.3
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	7.1	600	2	8.51E-01	2.6E-05	-4.6	11.0	300	1	9.6E-01	2.9E-05	-4.5	-95.5
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	20.8	600	2	8.17E-01	8.2E-05	-4.1	25.8	300	1	9.5E-01	9.5E-05	-4.0	-64.9
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	47.7	600	2	6.46E-01	6.5E-04	-3.2	53.1	300	1	8.9E-01	8.9E-04	-3.1	-6.5
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	68.5	600	2	3.79E-01	3.8E-03	-2.4	72.3	300	1	7.4E-01	7.4E-03	-2.1	46.6

022

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	71.2	-3.1	-114.3	0.2	-111.8
1.00E-05	-5.0	72.2	-3.5	-118.8	-0.5	-118.0
1.00E-04	-4.0	99.7	24.2	-62.4	25.2	-55.3
1.00E-03	-3.0	128.0	52.7	-2.8	51.8	4.5
1.00E-02	-2.0	149.0	72.7	50.5	74.1	58.0

Conc	Log(Conc)	Na
1.00E-05	-5.0	-82.3
1.00E-05	-5.0	-84.8
1.10E-04	-4.0	-38.5
1.01E-03	-3.0	14.8
1.00E-02	-2.0	67.2

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	281.9	280.2	117.1	259.8
5.00E-05	-4.3	285.4	282.8	118.8	259.9
6.00E-04	-3.2	227.9	228.2	119.0	221.5
6.00E-03	-2.2	175.1	176.3	102.7	172.9
6.00E-02	-1.2	119.2	120.3	51.9	116.8

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	0.2	600	2	8.63E-01	8.6E-06	-5.1	-3.1	300	1	9.6E-01	9.6E-06	-5.0	-114.3
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	-0.5	600	2	8.63E-01	8.6E-06	-5.1	-3.5	300	1	9.6E-01	9.6E-06	-5.0	-118.8
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	25.2	600	2	8.17E-01	8.2E-05	-4.1	24.2	300	1	9.5E-01	9.5E-05	-4.0	-62.4
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	51.8	600	2	6.46E-01	6.5E-04	-3.2	52.7	300	1	8.9E-01	8.9E-04	-3.1	-2.8
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	74.1	600	2	3.79E-01	3.8E-03	-2.4	72.7	300	1	7.4E-01	7.4E-03	-2.1	50.5

014

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	lr pH	Conc	Log(Conc)	Li(1)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	55.8	54.3	278.4	1.00E-03	-3.0	-0.4	1.03E-03	-3.0	238.7	411.8	136.8	80
3.00E-05	-4.5	33.6	26.1	272.3	1.00E-03	-3.0	-0.3	1.09E-03	-3.0	238.1	375.3	131.2	96
1.00E-05	-5.0	93.6	97.6	309.3	1.00E-03	-3.0	-0.5	1.30E-03	-2.9	234.3	419.6	126.0	152
1.00E-05	-5.0	60.0	62.0	294.0	1.00E-03	-3.0	-0.4	4.00E-03	-2.4	208.2	381.4	121.8	761
1.00E-05	-5.0	68.5	75.0	287.0	1.00E-03	-3.0	-0.8	3.10E-02	-1.5	158.5	377.7	119.3	5157

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	75.1	250	1	9.6E-01	9.6E-06	-5.0	-122.4	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-54.4
500	2	8.5E-01	2.5E-05	-4.6	88.8	250	1	9.6E-01	2.9E-05	-4.5	-92.5	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-35.2
500	2	8.1E-01	8.1E-05	-4.1	104.3	250	1	9.5E-01	9.5E-05	-4.0	-60.8	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-6.4
500	2	6.4E-01	6.4E-04	-3.2	131.8	250	1	8.8E-01	8.8E-04	-3.1	-2.3	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	46.9
500	2	3.5E-01	3.5E-03	-2.5	151.8	250	1	7.3E-01	7.3E-03	-2.1	50.7	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	98.0

018

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	lr pH	Conc	Log(Conc)	Li(1)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	38.3	34.4	138.0	1.00E-03	-3.0	-2.4	1.03E-03	-3.0	234.0	434.3	190.8	81
3.00E-05	-4.5	15.2	14.7	127.3	1.00E-03	-3.0	-2.3	1.09E-03	-3.0	232.9	381.8	184.9	97
1.00E-05	-5.0	36.7	35.9	143.6	1.00E-03	-3.0	-1.6	1.30E-03	-2.9	228.5	392.2	180.0	154
1.00E-05	-5.0	46.5	46.6	154.8	1.00E-03	-3.0	-1.7	4.00E-03	-2.4	202.7	372.8	175.3	799
1.00E-05	-5.0	62.1	63.4	163.8	1.00E-03	-3.0	1.4	3.10E-02	-1.5	153.1	368.9	171.3	5561

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	64.9	250	1	9.6E-01	9.6E-06	-5.0	-127.9	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-88.6
500	2	8.5E-01	2.5E-05	-4.6	78.1	250	1	9.6E-01	2.9E-05	-4.5	-95.3	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-69.9
500	2	8.1E-01	8.1E-05	-4.1	93.6	250	1	9.5E-01	9.5E-05	-4.0	-64.4	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-41.8
500	2	6.4E-01	6.4E-04	-3.2	120.8	250	1	8.8E-01	8.8E-04	-3.1	-5.1	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	9.8
500	2	3.5E-01	3.5E-03	-2.5	140.2	250	1	7.3E-01	7.3E-03	-2.1	46.9	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	61.8

020

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	lr pH	Conc	Log(Conc)	Li(1)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	35.8	42.7	205.5	1.00E-03	-3.0	0.8	1.03E-03	-3.0	235.5	289.5	205.2	82
3.00E-05	-4.5	13.2	20.5	198.6	1.00E-03	-3.0	1.3	1.09E-03	-3.0	234.7	257.8	199.4	98
1.00E-05	-5.0	32.8	40.6	210.3	1.00E-03	-3.0	0.7	1.30E-03	-2.9	229.7	276.2	193.9	157
1.00E-05	-5.0	37.6	45.5	221.2	1.00E-03	-3.0	1.3	4.00E-03	-2.4	204.6	278.2	189.5	813
1.00E-05	-5.0	49.0	56.7	226.1	1.00E-03	-3.0	0.3	3.10E-02	-1.5	154.9	280.0	185.9	5533

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	66.7	250	1	9.6E-01	9.6E-06	-5.0	-116.9	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-87.6
500	2	8.5E-01	2.5E-05	-4.6	80.3	250	1	9.6E-01	2.9E-05	-4.5	-87.4	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-68.6
500	2	8.1E-01	8.1E-05	-4.1	95.3	250	1	9.5E-01	9.5E-05	-4.0	-55.8	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-41.1
500	2	6.4E-01	6.4E-04	-3.2	124.0	250	1	8.8E-01	8.8E-04	-3.1	3.4	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	11.8
500	2	3.5E-01	3.5E-03	-2.5	144.2	250	1	7.3E-01	7.3E-03	-2.1	56.8	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	62.4

022

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	lr pH	Conc	Log(Conc)	Li(1)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	47.9	35.1	232.6	1.00E-03	-3.0	0.8	1.03E-03	-3.0	243.8	484.0	78.6	82
1.00E-05	-5.0	50.0	36.9	235.3	1.00E-03	-3.0	1.7	1.03E-03	-3.0	245.2	440.6	77.4	81
1.00E-05	-5.0	44.7	31.7	242.8	1.00E-03	-3.0	1.4	1.30E-03	-2.9	238.3	410.1	78.2	154
1.00E-05	-5.0	49.2	35.2	245.9	1.00E-03	-3.0	2.2	4.00E-03	-2.4	213.2	399.5	78.1	766
1.00E-05	-5.0	62.0	48.1	247.5	1.00E-03	-3.0	3.8	3.10E-02	-1.5	164.7	401.6	78.6	4584

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	9.9E-01	9.9E-06	-5.0	71.2	250	1	9.6E-01	9.6E-06	-5.0	-111.8	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-82.3
500	2	9.8E-01	9.8E-06	-5.0	72.2	250	1	9.6E-01	2.9E-05	-4.5	-118.0	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-84.8
500	2	9.6E-01	9.6E-05	-4.0	99.7	250	1	9.5E-01	9.5E-05	-4.0	-55.3	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-38.5
500	2	8.8E-01	8.8E-04	-3.1	128.0	250	1	8.8E-01	8.8E-04	-3.1	4.5	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	14.8
500	2	7.0E-01	7.0E-03	-2.2	149.0	250	1	7.3E-01	7.3E-03	-2.1	58.0	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	67.2

15.4. Summary of JPL "Before Delivery" Calibration Data (Feb 2007) for Flight Units 229918-014, -018, -020, -022

014

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	79.3	2.9	-104.4	5.3	-105.7
3.00E-05	-4.5	95.0	20.0	-71.2	21.7	-71.2
1.00E-04	-4.0	107.5	30.7	-49.5	32.5	-47.2
1.00E-03	-3.0	130.2	52.7	-1.5	54.6	5.5
1.00E-02	-2.0	150.9	71.8	53.9	76.2	56.2

Conc	Log(Conc)	Na
1.00E-05	-5.0	-46.0
3.00E-05	-4.5	-16.7
1.10E-04	-4.0	-2.0
1.01E-03	-3.0	48.7
1.00E-02	-2.0	102.5

Conc.(Cl)	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	272.4	274.2	165.8	254.4
1.50E-04	-3.8	243.9	247.9	161.2	236.5
6.00E-04	-3.2	222.5	223.9	160.3	216.3
6.00E-03	-2.2	173.0	176.2	141.5	170.6
6.00E-02	-1.2	116.9	118.9	103.8	112.0

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	5.3	600	2	8.63E-01	8.6E-06	-5.1	2.9	300	1	9.63E-01	9.6E-06	-5.0	-104.4
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	21.7	600	2	8.51E-01	2.6E-05	-4.6	20.0	300	1	9.59E-01	2.9E-05	-4.5	-71.2
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	32.5	600	2	8.17E-01	8.2E-05	-4.1	30.7	300	1	9.49E-01	9.5E-05	-4.0	-49.5
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	54.6	600	2	6.46E-01	6.5E-04	-3.2	52.7	300	1	8.87E-01	8.9E-04	-3.1	-1.5
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	76.2	600	2	3.79E-01	3.8E-03	-2.4	71.8	300	1	7.38E-01	7.4E-03	-2.1	53.9

018

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	73.15	6.20	-107.49	-3.41	-103.65
3.00E-05	-4.5	87.41	21.26	-78.61	9.05	-74.95
1.00E-04	-4.0	102.47	36.27	-47.80	23.31	-43.77
1.00E-03	-3.0	121.81	54.61	-6.51	42.59	-2.73
1.00E-02	-2.0	141.59	74.02	46.62	62.36	51.02

Conc	Log(Conc)	Na
1.00E-05	-5.0	-75.38
3.00E-05	-4.5	-52.32
1.10E-04	-4.0	-34.47
1.01E-03	-3.0	12.89
1.00E-02	-2.0	65.59

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	268.23	269.23	144.07	248.77
1.50E-04	-3.8	246.72	248.59	135.76	236.37
6.00E-04	-3.2	216.66	217.84	134.27	214.61
6.00E-03	-2.2	176.36	177.54	110.04	179.16
6.00E-02	-1.2	119.52	119.64	56.47	120.33

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	-3.4	600	2	8.63E-01	8.6E-06	-5.1	6.2	300	1	9.63E-01	9.6E-06	-5.0	-107.5
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	9.1	600	2	8.51E-01	2.6E-05	-4.6	21.3	300	1	9.59E-01	2.9E-05	-4.5	-78.6
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	23.3	600	2	8.17E-01	8.2E-05	-4.1	36.3	300	1	9.49E-01	9.5E-05	-4.0	-47.8
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	42.6	600	2	6.46E-01	6.5E-04	-3.2	54.6	300	1	8.87E-01	8.9E-04	-3.1	-6.5
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	62.4	600	2	3.79E-01	3.8E-03	-2.4	74.0	300	1	7.38E-01	7.4E-03	-2.1	46.6

020

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	79.16	5.46	-106.75	2.23	-94.97
3.00E-05	-4.5	92.80	20.15	-80.22	14.88	-68.00
1.00E-04	-4.0	106.75	34.53	-48.54	28.89	-35.52
1.00E-03	-3.0	126.15	54.37	-7.62	48.97	4.59
1.00E-02	-2.0	146.36	72.90	45.69	69.49	58.77

Conc	Log(Conc)	Na
1.00E-05	-5.0	-73.27
3.00E-05	-4.5	-52.82
1.10E-04	-4.0	-35.65
1.01E-03	-3.0	13.02
1.00E-02	-2.0	65.03

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	264.89	269.35	189.32	206.62
1.50E-04	-3.8	243.75	247.59	169.49	198.62
6.00E-04	-3.2	214.55	217.09	153.43	186.28
6.00E-03	-2.2	175.43	177.92	126.21	159.32
6.00E-02	-1.2	117.04	119.95	67.76	106.56

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	2.2	600	2	8.63E-01	8.6E-06	-5.1	5.5	300	1	9.63E-01	9.6E-06	-5.0	-106.7
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	14.9	600	2	8.51E-01	2.6E-05	-4.6	20.1	300	1	9.59E-01	2.9E-05	-4.5	-80.2
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	28.9	600	2	8.17E-01	8.2E-05	-4.1	34.5	300	1	9.49E-01	9.5E-05	-4.0	-48.5
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	49.0	600	2	6.46E-01	6.5E-04	-3.2	54.4	300	1	8.87E-01	8.9E-04	-3.1	-7.6
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	69.5	600	2	3.79E-01	3.8E-03	-2.4	72.9	300	1	7.38E-01	7.4E-03	-2.1	45.7

022

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	80.22	4.34	-102.22	4.71	-95.47
3.00E-05	-4.5	94.91	18.91	-72.96	18.97	-65.90
1.00E-04	-4.0	109.79	33.72	-42.40	34.41	-34.72
1.00E-03	-3.0	127.08	51.52	-2.42	51.70	5.21
1.00E-02	-2.0	149.09	72.22	52.32	73.40	59.26

Conc	Log(Conc)	Na
1.00E-05	-5.0	-72.47
3.00E-05	-4.5	-47.24
1.10E-04	-4.0	-30.13
1.01E-03	-3.0	15.93
1.00E-02	-2.0	69.18

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	266.31	268.11	148.66	240.34
1.50E-04	-3.8	245.05	247.04	138.43	229.12
6.00E-04	-3.2	213.25	215.92	132.48	204.63
6.00E-03	-2.2	174.38	176.55	110.78	168.93
6.00E-02	-1.2	117.78	119.77	55.48	110.66

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	4.7	600	2	8.63E-01	8.6E-06	-5.1	4.3	300	1	9.63E-01	9.6E-06	-5.0	-102.2
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	19.0	600	2	8.51E-01	2.6E-05	-4.6	18.9	300	1	9.59E-01	2.9E-05	-4.5	-73.0
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	34.4	600	2	8.17E-01	8.2E-05	-4.1	33.7	300	1	9.49E-01	9.5E-05	-4.0	-42.4
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	51.7	600	2	6.46E-01	6.5E-04	-3.2	51.5	300	1	8.87E-01	8.9E-04	-3.1	-2.4
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	73.4	600	2	3.79E-01	3.8E-03	-2.4	72.2	300	1	7.38E-01	7.4E-03	-2.1	52.3

014

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(2)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	39.7	34.0	260.8	1.00E-03	-3.0	-1.4	1.03E-03	-3.0	235.8	401.2	45.7	92
3.00E-05	-4.5	15.2	9.6	250.8	1.00E-03	-3.0	-0.2	1.09E-03	-3.0	233.4	352.9	45.2	125
1.00E-05	-5.0	40.8	37.4	254.6	1.00E-03	-3.0	-1.2	1.30E-03	-2.9	230.3	370.5	44.2	197
1.00E-05	-5.0	50.5	50.0	266.6	1.00E-03	-3.0	-1.6	4.00E-03	-2.4	205.0	375.0	43.3	821
1.00E-05	-5.0	64.0	67.1	275.3	1.00E-03	-3.0	-1.1	3.10E-02	-1.5	156.3	384.7	42.5	5696

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	79.3	250	1	9.6E-01	9.6E-06	-5.0	-105.7	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-46.0
500	2	8.5E-01	2.5E-05	-4.6	95.0	250	1	9.6E-01	2.9E-05	-4.5	-71.2	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-16.7
500	2	8.1E-01	8.1E-05	-4.1	107.5	250	1	9.5E-01	9.5E-05	-4.0	-47.2	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-2.0
500	2	6.4E-01	6.4E-04	-3.2	130.2	250	1	8.8E-01	8.8E-04	-3.1	5.5	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	48.7
500	2	3.5E-01	3.5E-03	-2.5	150.9	250	1	7.3E-01	7.3E-03	-2.1	56.2	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	102.5

018

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(1)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	21.70	25.48	259.93	1.00E-03	-3.0	1.36	1.03E-03	-3.0	231.2	344.8	-24.6	95
3.00E-05	-4.5	-0.56	4.15	247.66	1.00E-03	-3.0	2.48	1.09E-03	-3.0	230.1	323.4	-24.8	126
1.00E-05	-5.0	22.50	27.28	253.61	1.00E-03	-3.0	1.74	1.30E-03	-2.9	222.9	345.9	-24.9	236
1.00E-05	-5.0	38.12	42.90	261.91	1.00E-03	-3.0	1.36	4.00E-03	-2.4	203.0	358.7	-25.9	835
1.00E-05	-5.0	53.06	58.09	270.04	1.00E-03	-3.0	2.67	3.10E-02	-1.5	152.6	366.5	-24.4	5822

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	73.2	250	1	9.6E-01	9.6E-06	-5.0	-103.6	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-75.4
500	2	8.5E-01	2.5E-05	-4.6	87.4	250	1	9.6E-01	2.9E-05	-4.5	-74.9	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-52.3
500	2	8.1E-01	8.1E-05	-4.1	102.5	250	1	9.5E-01	9.5E-05	-4.0	-43.8	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-34.5
500	2	6.4E-01	6.4E-04	-3.2	121.8	250	1	8.8E-01	8.8E-04	-3.1	-2.7	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	12.9
500	2	3.5E-01	3.5E-03	-2.5	141.6	250	1	7.3E-01	7.3E-03	-2.1	51.0	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	65.6

020

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(1)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	15.87	21.88	300.85	1.00E-03	-3.0	1.92	1.03E-03	-3.0	232.5	365.0	57.6	96
3.00E-05	-4.5	-7.56	-2.48	289.56	1.00E-03	-3.0	2.23	1.09E-03	-3.0	230.9	336.4	53.7	126
1.00E-05	-5.0	15.81	21.39	296.44	1.00E-03	-3.0	1.30	1.30E-03	-2.9	222.4	350.4	52.4	238
1.00E-05	-5.0	32.05	36.45	306.55	1.00E-03	-3.0	2.48	4.00E-03	-2.4	203.7	357.0	50.1	844
1.00E-05	-5.0	45.56	51.76	312.44	1.00E-03	-3.0	1.36	3.10E-02	-1.5	152.6	350.5	50.2	5773

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	79.2	250	1	9.6E-01	9.6E-06	-5.0	-95.0	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-73.3
500	2	8.5E-01	2.5E-05	-4.6	92.8	250	1	9.6E-01	2.9E-05	-4.5	-68.0	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-52.8
500	2	8.1E-01	8.1E-05	-4.1	106.7	250	1	9.5E-01	9.5E-05	-4.0	-35.5	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-35.6
500	2	6.4E-01	6.4E-04	-3.2	126.2	250	1	8.8E-01	8.8E-04	-3.1	4.6	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	13.0
500	2	3.5E-01	3.5E-03	-2.5	146.4	250	1	7.3E-01	7.3E-03	-2.1	58.8	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	65.0

022

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(1)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	24.92	11.65	304.07	1.00E-03	-3.0	0.99	1.03E-03	-3.0	243.3	402.8	23.8	95
3.00E-05	-4.5	2.85	-9.17	291.11	1.00E-03	-3.0	1.12	1.09E-03	-3.0	242.1	371.1	20.6	124
1.00E-05	-5.0	26.59	13.20	293.53	1.00E-03	-3.0	1.36	1.30E-03	-2.9	233.9	389.3	17.6	239
1.00E-05	-5.0	41.97	27.65	301.40	1.00E-03	-3.0	0.31	4.00E-03	-2.4	212.6	395.5	16.1	808
1.00E-05	-5.0	58.52	44.08	310.21	1.00E-03	-3.0	1.55	3.10E-02	-1.5	163.4	392.8	17.1	5002

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	80.2	250	1	9.6E-01	9.6E-06	-5.0	-95.5	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-72.5
500	2	8.5E-01	2.5E-05	-4.6	94.9	250	1	9.6E-01	2.9E-05	-4.5	-65.9	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-47.2
500	2	8.1E-01	8.1E-05	-4.1	109.8	250	1	9.5E-01	9.5E-05	-4.0	-34.7	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-30.1
500	2	6.4E-01	6.4E-04	-3.2	127.1	250	1	8.8E-01	8.8E-04	-3.1	5.2	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	15.9
500	2	3.5E-01	3.5E-03	-2.5	149.1	250	1	7.3E-01	7.3E-03	-2.1	59.3	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	69.2

15.5. Summary of JPL Final "Before Delivery" Calibration Data (March 2007) for Flight Units 229918-014, -018, -020, -022

014

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	73.6	-2.6	-117.3	0.9	-112.8
3.00E-05	-4.5	87.3	11.3	-88.9	12.5	-88.6
1.00E-04	-4.0	102.5	26.0	-57.6	28.1	-64.0
1.00E-03	-3.0	130.6	53.9	0.2	55.4	5.0
1.00E-02	-2.0	151.7	74.3	53.7	76.2	58.1

Conc	Log(Conc)	Na
1.00E-05	-5.0	-51.4
3.00E-05	-4.5	-29.2
1.10E-04	-4.0	-0.6
1.01E-03	-3.0	53.4
1.00E-02	-2.0	105.6

Conc.(Cl)	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	284.7	285.1	187.4	259.0
1.50E-04	-3.8	259.9	260.4	182.9	244.5
6.00E-04	-3.2	228.3	232.0	178.8	222.5
6.00E-03	-2.2	175.1	176.5	159.9	170.8
6.00E-02	-1.2	118.6	120.6	118.5	113.2

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	0.9	600	2	8.63E-01	8.6E-06	-5.1	-2.6	300	1	9.6E-01	9.6E-06	-5.0	-117.3
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	12.5	600	2	8.51E-01	2.6E-05	-4.6	11.3	300	1	9.6E-01	2.9E-05	-4.5	-88.9
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	28.1	600	2	8.17E-01	8.2E-05	-4.1	26.0	300	1	9.5E-01	9.5E-05	-4.0	-57.6
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	55.4	600	2	6.46E-01	6.5E-04	-3.2	53.9	300	1	8.9E-01	8.9E-04	-3.1	0.2
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	76.2	600	2	3.79E-01	3.8E-03	-2.4	74.3	300	1	7.4E-01	7.4E-03	-2.1	53.7

018

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	64.0	-2.0	-128.4	-11.2	-121.61
3.00E-05	-4.5	77.3	10.4	-100.5	-0.7	-95.39
1.00E-04	-4.0	91.1	25.3	-69.3	14.1	-63.78
1.00E-03	-3.0	119.4	54.5	-8.2	40.7	-3.90
1.00E-02	-2.0	140.6	74.5	46.4	63.0	49.15

Conc	Log(Conc)	Na
1.00E-05	-5.0	-87.0
3.00E-05	-4.5	-66.5
1.10E-04	-4.0	-39.7
1.01E-03	-3.0	13.3
1.00E-02	-2.0	66.9

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	282.62	280.42	173.80	252.52
1.50E-04	-3.8	262.66	262.87	159.36	242.23
6.00E-04	-3.2	229.93	230.70	149.57	222.89
6.00E-03	-2.2	173.83	176.53	114.86	176.72
6.00E-02	-1.2	120.71	120.74	56.53	120.62

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	-11.2	600	2	8.63E-01	8.6E-06	-5.1	-2.0	300	1	9.6E-01	9.6E-06	-5.0	-128.4
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	-0.7	600	2	8.51E-01	2.6E-05	-4.6	10.4	300	1	9.6E-01	2.9E-05	-4.5	-100.5
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	14.1	600	2	8.17E-01	8.2E-05	-4.1	25.3	300	1	9.5E-01	9.5E-05	-4.0	-69.3
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	40.7	600	2	6.46E-01	6.5E-04	-3.2	54.5	300	1	8.9E-01	8.9E-04	-3.1	-8.2
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	63.0	600	2	3.79E-01	3.8E-03	-2.4	74.5	300	1	7.4E-01	7.4E-03	-2.1	46.4

020

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	65.1	-3.6	-124.6	-6.6	-114.86
3.00E-05	-4.5	79.0	10.6	-97.4	6.1	-85.79
1.00E-04	-4.0	94.7	24.7	-66.1	20.5	-51.76
1.00E-03	-3.0	123.0	52.3	-7.4	47.7	7.25
1.00E-02	-2.0	143.8	73.9	47.0	70.5	60.43

Conc	Log(Conc)	Na
1.00E-05	-5.0	-88.1
3.00E-05	-4.5	-68.5
1.10E-04	-4.0	-40.1
1.01E-03	-3.0	12.3
1.00E-02	-2.0	66.0

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	281.63	284.20	179.44	203.25
1.50E-04	-3.8	260.92	263.56	167.11	197.23
6.00E-04	-3.2	228.13	231.32	158.00	190.10
6.00E-03	-2.2	174.21	176.16	120.93	158.37
6.00E-02	-1.2	118.54	121.74	67.07	107.98

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	-6.6	600	2	8.63E-01	8.6E-06	-5.1	-3.6	300	1	9.6E-01	9.6E-06	-5.0	-124.6
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	6.1	600	2	8.51E-01	2.6E-05	-4.6	10.6	300	1	9.6E-01	2.9E-05	-4.5	-97.4
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	20.5	600	2	8.17E-01	8.2E-05	-4.1	24.7	300	1	9.5E-01	9.5E-05	-4.0	-66.1
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	47.7	600	2	6.46E-01	6.5E-04	-3.2	52.3	300	1	8.9E-01	8.9E-04	-3.1	-7.4
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	70.5	600	2	3.79E-01	3.8E-03	-2.4	73.9	300	1	7.4E-01	7.4E-03	-2.1	47.0

022

Conc	Log(Conc)	Ba	Ca	K	Mg	NH4
1.00E-05	-5.0	67.7	-6.0	-118.6	-4.0	-115.04
3.00E-05	-4.5	82.4	10.2	-90.5	9.4	-84.11
1.00E-04	-4.0	97.2	25.2	-60.2	22.9	-53.24
1.00E-03	-3.0	125.5	50.5	-2.4	50.2	4.77
1.00E-02	-2.0	146.6	72.0	51.9	73.3	59.38

Conc	Log(Conc)	Na
1.00E-05	-5.0	-88.3
3.00E-05	-4.5	-66.3
1.10E-04	-4.0	-36.8
1.01E-03	-3.0	15.6
1.00E-02	-2.0	69.1

Conc	Log(Conc)	Cl Ref	Cl	I	Br
5.00E-05	-4.3	280.32	280.35	139.53	245.70
1.50E-04	-3.8	259.75	258.29	138.66	235.42
6.00E-04	-3.2	228.44	229.65	133.51	213.72
6.00E-03	-2.2	174.14	175.97	101.34	165.31
6.00E-02	-1.2	119.16	120.43	50.70	109.96

Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Mg	α	z	γ	Activity	Log(a)	Ca	α	z	γ	Activity	Log(a)	K
1.0E-05	-5.0	1.2E-03	1.1E-03	800	2	8.65E-01	8.7E-06	-5.1	-4.0	600	2	8.63E-01	8.6E-06	-5.1	-6.0	300	1	9.6E-01	9.6E-06	-5.0	-118.6
3.0E-05	-4.5	1.4E-03	1.4E-03	800	2	8.54E-01	2.6E-05	-4.6	9.4	600	2	8.51E-01	2.6E-05	-4.6	10.2	300	1	9.6E-01	2.9E-05	-4.5	-90.5
1.0E-04	-4.0	2.3E-03	2.2E-03	800	2	8.22E-01	8.2E-05	-4.1	22.9	600	2	8.17E-01	8.2E-05	-4.1	25.2	300	1	9.5E-01	9.5E-05	-4.0	-60.2
1.0E-03	-3.0	1.2E-02	1.3E-02	800	2	6.62E-01	6.6E-04	-3.2	50.2	600	2	6.46E-01	6.5E-04	-3.2	50.5	300	1	8.9E-01	8.9E-04	-3.1	-2.4
1.0E-02	-2.0	7.2E-02	1.2E-01	800	2	4.26E-01	4.3E-03	-2.4	73.3	600	2	3.79E-01	3.8E-03	-2.4	72.0	300	1	7.4E-01	7.4E-03	-2.1	51.9

014

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(2)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	53.1	48.7	290.6	1.00E-03	-3.0	-1.0	1.03E-03	-3.0	236.7	450.8	124.7	85
3.00E-05	-4.5	29.1	23.4	276.8	1.00E-03	-3.0	-1.1	1.09E-03	-3.0	235.6	379.3	117.5	102
1.00E-05	-5.0	52.4	49.6	287.0	1.00E-03	-3.0	-0.5	1.30E-03	-2.9	231.1	364.3	112.4	164
1.00E-05	-5.0	59.1	56.4	293.5	1.00E-03	-3.0	-0.7	4.00E-03	-2.4	204.8	369.0	109.2	829
1.00E-05	-5.0	70.5	69.1	295.4	1.00E-03	-3.0	-0.9	3.10E-02	-1.5	156.5	367.1	106.6	5742

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	73.6	250	1	9.6E-01	9.6E-06	-5.0	-112.8	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-51.4
500	2	8.5E-01	2.5E-05	-4.6	87.3	250	1	9.6E-01	2.9E-05	-4.5	-88.6	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-29.2
500	2	8.1E-01	8.1E-05	-4.1	102.5	250	1	9.5E-01	9.5E-05	-4.0	-64.0	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-0.6
500	2	6.4E-01	6.4E-04	-3.2	130.6	250	1	8.8E-01	8.8E-04	-3.1	5.0	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	53.4
500	2	3.5E-01	3.5E-03	-2.5	151.7	250	1	7.3E-01	7.3E-03	-2.1	58.1	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	105.6

018

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(1)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	37.00	43.45	276.20	1.00E-03	-3.0	3.72	1.03E-03	-3.0	232.3	359.6	-3.3	87
3.00E-05	-4.5	12.40	17.73	263.43	1.00E-03	-3.0	2.67	1.09E-03	-3.0	230.4	331.6	-4.4	104
1.00E-05	-5.0	35.02	40.60	273.10	1.00E-03	-3.0	1.61	1.30E-03	-2.9	224.6	352.1	-5.1	168
1.00E-05	-5.0	40.85	47.11	278.62	1.00E-03	-3.0	2.17	4.00E-03	-2.4	199.3	358.6	-4.8	876
1.00E-05	-5.0	54.79	60.31	282.58	1.00E-03	-3.0	4.09	3.10E-02	-1.5	152.5	370.5	-3.8	6223

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	64.0	250	1	9.6E-01	9.6E-06	-5.0	-121.6	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-87.0
500	2	8.5E-01	2.5E-05	-4.6	77.3	250	1	9.6E-01	2.9E-05	-4.5	-95.4	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-66.5
500	2	8.1E-01	8.1E-05	-4.1	91.1	250	1	9.5E-01	9.5E-05	-4.0	-63.8	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-39.7
500	2	6.4E-01	6.4E-04	-3.2	119.4	250	1	8.8E-01	8.8E-04	-3.1	-3.9	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	13.3
500	2	3.5E-01	3.5E-03	-2.5	140.6	250	1	7.3E-01	7.3E-03	-2.1	49.2	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	66.9

020

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(1)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	32.29	36.57	299.51	1.00E-03	-3.0	1.92	1.03E-03	-3.0	229.3	349.5	44.8	88
3.00E-05	-4.5	7.31	11.90	285.93	1.00E-03	-3.0	1.98	1.09E-03	-3.0	228.7	321.8	42.7	105
1.00E-05	-5.0	31.18	34.90	298.45	1.00E-03	-3.0	3.35	1.30E-03	-2.9	224.5	343.7	42.6	171
1.00E-05	-5.0	36.82	40.85	303.85	1.00E-03	-3.0	2.67	4.00E-03	-2.4	198.2	346.7	43.7	885
1.00E-05	-5.0	49.96	54.11	311.66	1.00E-03	-3.0	2.48	3.10E-02	-1.5	151.1	348.0	44.0	6210

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	65.1	250	1	9.6E-01	9.6E-06	-5.0	-114.9	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-88.1
500	2	8.5E-01	2.5E-05	-4.6	79.0	250	1	9.6E-01	2.9E-05	-4.5	-85.8	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-68.5
500	2	8.1E-01	8.1E-05	-4.1	94.7	250	1	9.5E-01	9.5E-05	-4.0	-51.8	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-40.1
500	2	6.4E-01	6.4E-04	-3.2	123.0	250	1	8.8E-01	8.8E-04	-3.1	7.3	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	12.3
500	2	3.5E-01	3.5E-03	-2.5	143.8	250	1	7.3E-01	7.3E-03	-2.1	60.4	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	66.0

022

Conc HCO3-	Log(Conc) HCO3-	pH1	pH2	Ir pH	Conc	Log(Conc)	Li(1)	Conc	Log (Conc)	NO3	ORP	CO2	EC (uS)
1.00E-05	-5.0	48.53	36.94	296.04	1.00E-03	-3.0	-0.74	1.03E-03	-3.0	238.6	345.3	51.8	86
3.00E-05	-4.5	19.40	7.75	279.24	1.00E-03	-3.0	0.74	1.09E-03	-3.0	238.8	318.6	47.5	103
1.00E-05	-5.0	46.49	33.66	293.49	1.00E-03	-3.0	-0.06	1.30E-03	-2.9	234.7	339.4	45.6	166
1.00E-05	-5.0	53.68	39.36	300.19	1.00E-03	-3.0	-0.68	4.00E-03	-2.4	208.5	349.0	44.0	839
1.00E-05	-5.0	62.91	49.96	302.54	1.00E-03	-3.0	1.18	3.10E-02	-1.5	161.0	357.8	43.2	5362

α	z	γ	Activity	Log(a)	Ba	α	z	γ	Activity	Log(a)	NH4	Conc	Log(Conc)	μ(EC)	μ(calc)	α	z	γ	Activity	Log(a)	Na
500	2	8.6E-01	8.6E-06	-5.1	67.7	250	1	9.6E-01	9.6E-06	-5.0	-115.0	1.00E-05	-5.0	1.2E-03	1.1E-03	450	1	9.6E-01	9.6E-06	-5.0	-88.3
500	2	8.5E-01	2.5E-05	-4.6	82.4	250	1	9.6E-01	2.9E-05	-4.5	-84.1	3.00E-05	-4.5	1.4E-03	1.4E-03	450	1	9.6E-01	2.9E-05	-4.5	-66.3
500	2	8.1E-01	8.1E-05	-4.1	97.2	250	1	9.5E-01	9.5E-05	-4.0	-53.2	1.10E-04	-4.0	2.3E-03	2.2E-03	450	1	9.5E-01	1.0E-04	-4.0	-36.8
500	2	6.4E-01	6.4E-04	-3.2	125.5	250	1	8.8E-01	8.8E-04	-3.1	4.8	1.01E-03	-3.0	1.2E-02	1.3E-02	450	1	8.9E-01	9.0E-04	-3.0	15.6
500	2	3.5E-01	3.5E-03	-2.5	146.6	250	1	7.3E-01	7.3E-03	-2.1	59.4	1.00E-02	-2.0	7.2E-02	1.2E-01	450	1	7.6E-01	7.6E-03	-2.1	69.1

15.6. Summary of final pH Calibration Data for Flight Units 229918-014, -018, -020, -022

Extracted ISE Data (analysed) for Flight Beakers, using TS solutions
Ir pH and PVC pH sensors

	Ir pH	upper pH1	lower pH2
F229918-014	**BKR 14a**	**BKR 14b**	**BKR 14c**
TS21 air	**6.60**	**6.60**	**6.60**
TS21 acid	**5.00**	**5.00**	**5.00**
mV (MEAN)	268.49	22.81	24.36
mV (MEAN)	362.40	110.10	114.19
SD	1.27	1.41	1.98
SD	1.98	2.12	1.56

F229918-014	BKR 14a	BKR 14b	BKR 14c
Slope	-58.70	-54.55	-56.14
intercept	655.89	382.86	394.89

F229918-018	BKR 18a	BKR 18b	BKR 18c
TS21 air	**6.73**	**6.73**	**6.73**
TS21 acid	**4.97**	**4.97**	**4.97**
mean	198.44	2.29	4.71
mean	297.75	106.75	109.91
SD	1.81	2.02	1.77
SD	1.07	1.49	2.04

F229918-018	BKR 18a	BKR 18b	BKR 18c
slope	-56.43	-59.35	-59.77
intercept	578.19	401.72	406.98

F229918-020	BKR 20a	BKR 20b	BKR 20c
TS21 air	**6.74**	**6.74**	**6.74**
TS21 acid	**5.02**	**5.02**	**5.02**
mean	256.96	-5.77	1.98
mean	347.09	90.51	100.43
SD	1.77	1.86	2.36
SD	1.66	2.14	1.42

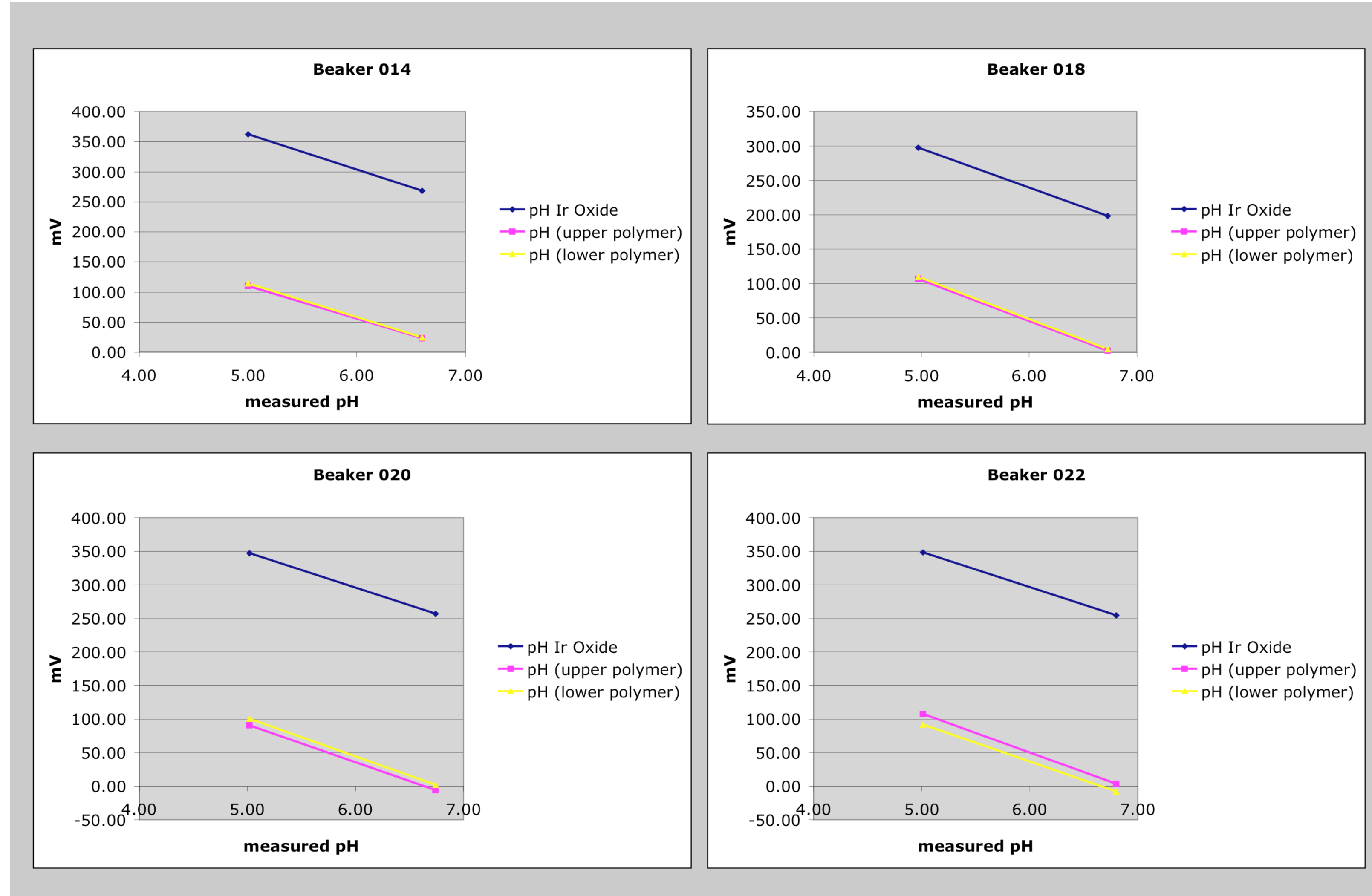
F229918-020	BKR 20a	BKR 20b	BKR 20c
slope	-52.40	-55.97	-57.23
intercept	610.16	371.49	387.74

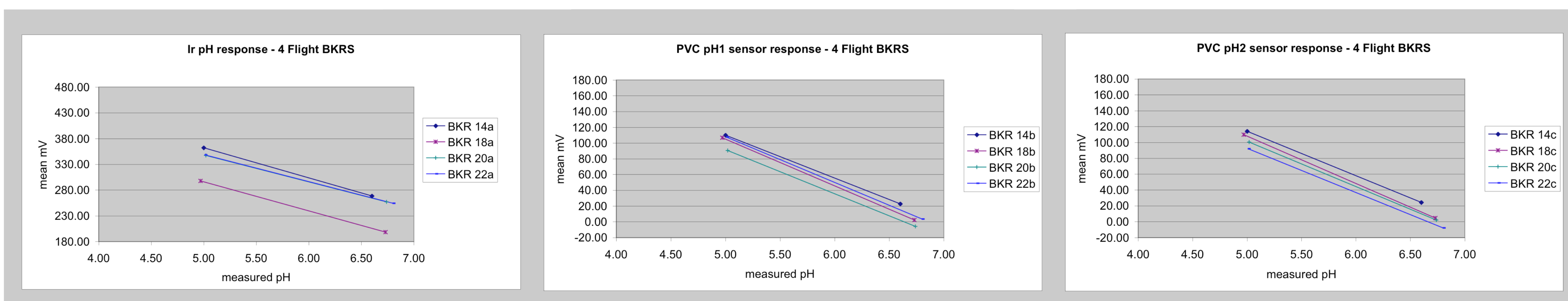
F229918-022	BKR 22a	BKR 22b	BKR 22c
TS21 air	**6.80**	**6.80**	**6.80**
TS21 acid	**5.01**	**5.01**	**5.01**
mean	254.48	3.60	-7.87
mean	348.27	107.62	92.00
SD	1.62	1.42	1.15
SD	2.15	1.63	1.57

F229918-022	BKR 22a	BKR 22b	BKR 22c
slope	-52.40	-58.11	-55.79
intercept	610.79	398.76	371.52

Summary of slope and intercept for pH sensors in flight beakers

Beaker s/n	014		018		020		022	
	Slope (mV/pH)	Intercept (mV)	Slope (mV/pH)	Intercept (mV)	Slope (mV/pH)	Intercept (mV)	Slope (mV/pH)	Intercept (mV)
Ir pH	-58.70	655.89	-56.43	578.19	-52.40	610.16	-52.40	610.79
pH 1 (upper)	-54.55	382.86	-59.35	401.72	-55.97	371.49	-58.11	398.76
pH 2 (bottom)	-56.14	394.89	-59.77	406.98	-57.23	387.74	-55.79	371.52





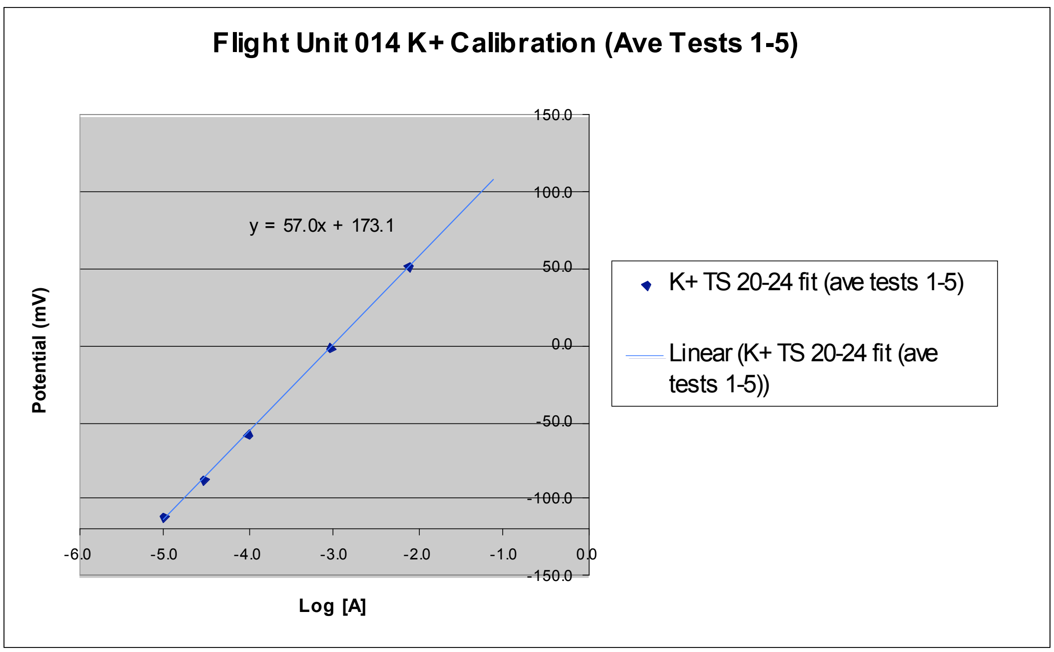
16. Appendix D— WCL Flight Unit Calibration Method Comparison (Tufts)

To determine a valid linear calibration curve for the ISE sensors in the WCL beakers, two pieces of information are needed, the slope (sensitivity) in mV/decade activity, and an intercept (mV). However, there are several different ways that the slope and an intercept can be obtained for any given sensor. In the accompanying excel spreadsheet we used six different methods to obtain calibration curves from the existing preflight test data for beaker units 14, 18, 20, and 22.

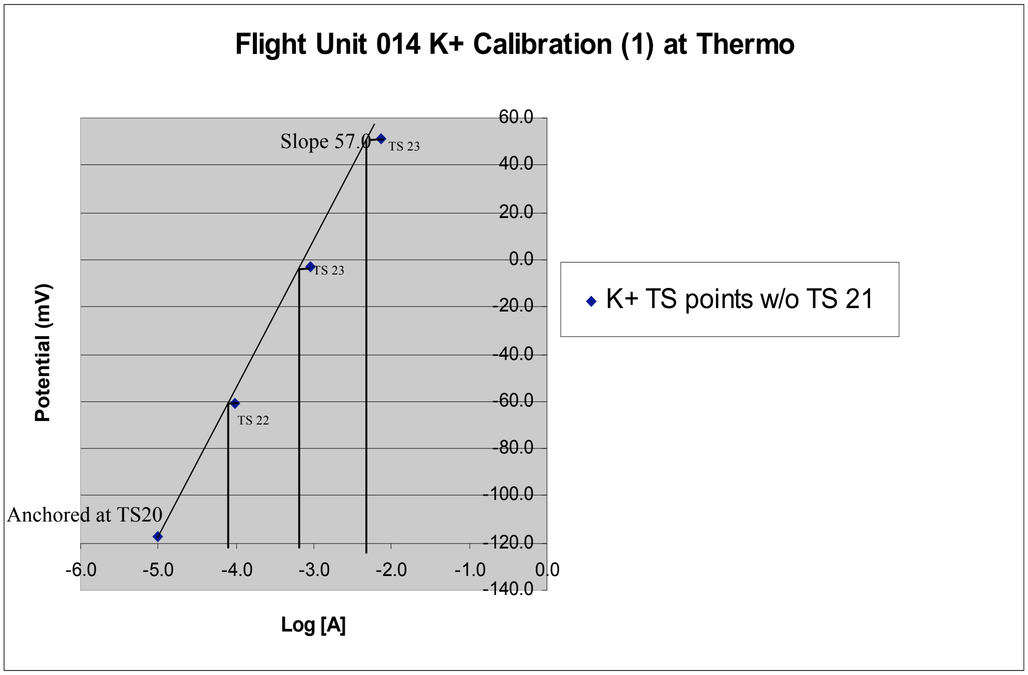
The four integrated WCL beakers were each calibrated five times: (1) by Thermo before shipping, and then at JPL, (2) when received, (3) for post protoflight, (4) for functional tests, and (5) as a final test before delivery to LMA. Each calibration was generated by plotting the measured potential of the ISE (mV) as a function of the Log(activity) for the five test solutions, TS20, TS21, TS22, TS23, and TS24. The goal was to compare how accurately each calibration method then predicted the activities of the TS22, TS23, and TS24 solutions and thus help in determining an overall best method of calibrating the WCLs.

Calibration Methods

(1) Average TS 20-24 slope anchored at TS 20 point
This method determines the slope for an ISE by averaging the results from all five calibrations and creating a linear fit curve. Below is an example for the K^+ ISE in Flight Unit 14.



To determine how well the slope would predict the activities of the TS22-24 solutions for a single experiment, we used the average slope of 57.0 mV/decade and anchored it to start at the TS20 point. This line was then used in combination with the potential values (mV) of TS 22-24 to predict the Log(activity) of each solution, TS 22-24, for a given experiment (see below).



Standard deviations and percent errors were calculated based on predicted and actual TS 22-24 activities. The same procedure was repeated for every electrode in every flight beaker, and the results of standard deviations and percent errors were all averaged.

(2) Average TS 20-24 slope anchored at TS 21 point
Same method as above except the average slope anchored at the TS 21 point.

(3) Slope based on TS 20 and 21 points
A new calibration slope is determined for EACH experiment based on only the TS 20 and 21 points for that particular experiment (a two point calibration!).

(4) Nernstian slope anchored at TS 20 pt.
Slope is assumed to be Nernstian (59.2 for ±1 ions, 29.6 for +2 ions) and is anchored at TS 20 pt.

(5) Nernstian slope anchored at TS 21 pt.
Slope is assumed to be Nernstian (59.2 for ±1 ions, 29.6 for +2 ions) and is anchored at TS 21 pt.

(6) Average TS 21-24 slope anchored at TS 21 pt.
Slope determined same as first method but without TS 20 pt. Slope is anchored at TS 21 pt. This method was examined since the TS 20 pt is at the lowest end of the linear range.

Conclusion: Using method 2 (average slope anchored at the TS21 point) appears to give the best analytical result. Note however, there is not much difference between methods 1 and 2, and even methods 4, 5, and 6 are within close proximity. Method #3 gives the worst result.

The tab labeled “Overall Summary” in the Excel spreadsheet presents the results in two graphs.

Calibration method comparison across all electrodes, all predictions and all flight units

Jason Kapit 07/10/2007

CALIBRATION METHOD

		Avg TS20-24 slope anchored at TS20 pt		Avg TS20-24 slope anchored at TS21 pt		Slope based on both TS20 and 21 pts		Nernstian slope through each TS20 pt		Nernstian slope anchored at TS20 pt		Avg TS21-24 slope anchored at TS21 pt	
Flight unit 014	**All Electrodes**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**
	TS22 Prediction	0.05	9.4	0.06	5.7	0.15	11.0	0.05	17.1	0.06	10.2	0.15	11.0
	TS23 Prediction	0.08	9.0	0.12	4.9	0.43	56.5	0.07	20.5	0.11	14.6	0.43	56.5
	TS24 Prediction	0.08	2.7	0.12	6.3	0.68	154.0	0.08	30.3	0.11	24.7	0.68	154
Flight unit 018	**All Electrodes**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**
	TS22 Prediction	0.05	11.1	0.03	6.3	0.1	20.2	0.04	15.8	0.02	7.2	0.03	7.6
	TS23 Prediction	0.11	10.5	0.12	5.7	0.41	97.8	0.10	24.7	0.11	16.2	0.12	8.2
	TS24 Prediction	0.11	3.4	0.12	7.7	0.73	453.0	0.10	34.7	0.11	27.2	0.12	5.8
Flight unit 02-	**All Electrodes**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**
	TS22 Prediction	0.05	9.6	0.05	6.7	0.67	22.1	0.05	15.5	0.05	5.6	0.05	6.9
	TS23 Prediction	0.12	10.0	0.13	6.2	1.50	56.2	0.11	23.3	0.13	13.8	0.13	5.0
	TS24 Prediction	0.13	4.1	0.14	9.2	2.41	119.1	0.12	32.0	0.13	23.6	0.14	5.2
Flight unit 022	**All Electrodes**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**
	TS22 Prediction	0.06	11.2	0.06	5.9	0.69	22.2	0.05	14.4	0.06	6.3	0.06	6.6
	TS23 Prediction	0.12	9.1	0.14	3.6	1.61	51.5	0.11	23.5	0.13	17.3	0.14	4.2
	TS24 Prediction	0.11	3.1	0.14	8.5	2.66	84.8	0.11	30.2	0.13	24.6	0.14	6.5
All Flight Units	**All Electrodes**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**	**StD Log[A]**	**% error [A]**
	All Predictions	0.09	7.8	0.10	6.41	1.01	95.7	0.08	23.5	0.10	15.9	0.18	23.1

Best Results