527505

Sandia National Laboratories
Waste Isolation Pilot Plant

Verification of the Definition of Generic Weep Brine and the Development of a Recipe for this Brine

BOE 1.3.5.1.2

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1 ABBREVIATIONS, ACRONYMS, AND INITIALISMS

Table 1 defines the abbreviations, acronyms, and initialisms used in this report.

Table 1. Abbreviations, Acronyms, and Initialisms.

Abbreviation, Acronym, or Initialism	Definition
ACS	Anna C. Snider
aq	aqueous
ASTP	(WIPP) Actinide Source Term Program
B, $B(OH)_3(aq)$	boron, boric acid
Br, Br^-	bromine, bromide (ion)
Brine A	a synthetic brine representative of intergranular Salado brines
Ca, Ca^{2+}	calcium, calcium ion
Cl, Cl^-	chlorine, chloride ion
DOE	(U.S.) Department of Energy
ERDA-6	Energy Research and Development Administration (WIPP Well) 6, a synthetic brine representative of fluids in Castile brine reservoirs
Fm.	Formation or formation, depending on usage
g	gram(s)
GGP	(WIPP) Gas Generation Program
GWB	Generic Weep Brine, a synthetic brine representative of intergranular Salado brines
H_2O	water
K, K^+	potassium, potassium ion
kg	kilogram(s)
L	liter(s)
Li, Li^+	lithium, lithium ion
M	molar
Mg, Mg^{2+}	magnesium, magnesium ion
MgO	magnesium oxide, the WIPP engineered barrier
mol	mole(s)
Na, Na^+	sodium, sodium ion
OH^-	hydroxide ion
PAB-1	(WIPP) Performance Assessment Brine-1
ppm	parts per million
ppt	parts per thousand
SB-1	(WIPP) Standard Brine-1
SNL	Sandia National Laboratories

Table 1. Abbreviations, Acronyms, and Initialisms (cont.).

Abbreviation, Acronym, or Initialism	Definition
SO_4^{2-}	sulfate ion
WIPP	(U.S. DOE) Waste Isolation Pilot Plant

2 INTRODUCTION AND OBJECTIVES

This report describes the independent verification of: (1) the calculations used to define Generic Weep Brine (GWB), and (2) the calculations used to develop a recipe for this brine.

GWB is a synthetic Waste Isolation Pilot Plant (WIPP) brine representing the average composition of intergranular fluids from the Salado Formation at or near the stratigraphic horizon of the WIPP underground workings. The work described in this memo was carried out according to the specifications of Brush and Xiong (2003, Subsection 7.1, Documentation of GWB).

Well-defined, quality-assured brines and recipes for these brines are needed for laboratory and modeling studies of WIPP chemistry. Brush (1990) compared several such brines, and specified the use of two synthetic solutions to simulate brines that could be present in the repository after filling and sealing: (1) Brine A, representative of intergranular (grain-boundary) brines from the Salado Formation at or near the stratigraphic horizon of the repository (Molecke, 1983); and (2) ERDA-6, typical of fluids in brine reservoirs in the underlying Castile Fm. (Popielak et al., 1983). These brines were used for most of the lab and modeling studies carried out for the WIPP Gas Generation Program (Brush, 1990). The WIPP Actinide Source Term Program also used these brines (Brush and Xiong, 1993).

Krumhansl et al. (1991) carried out chemical analyses of "brine weeps," intergranular fluids that seep into the WIPP from the disturbed rock zone surrounding the excavations. Later, Krumhansl used the results of these analyses to define the synthetic brine GWB for use in laboratory studies of the efficacy of MgO, which were then being initiated at Sandia National Laboratories (SNL) in Albuquerque. GWB was developed because investigators such as Krumhansl believed that the chemical behavior of MgO is sensitive to the Mg^{2+} concentration of the solutions used for lab experiments, and because the Mg^{2+} concentration of Brine A (1.44 M) is significantly higher than the average Mg^{2+} concentration of intergranular Salado brines, about 1.0 M (Brush, 1989; Brush, 1990).

Once he defined this synthetic brine, Krumhansl compared it to a number of other standard WIPP brines and concluded that it most closely resembles a synthetic Salado brine termed PAB-1 (Brush, 1989; Brush, 1990; Molecke, 1990). (Brush (1989) referred to his brine as "Performance Assessment Brine-1" in the memo that originally defined it, but Brush (1990) subsequently renamed it "Standard Brine-1," or SB-1.) Finally, Krumahnsl developed a recipe for this brine. GWB was then used, along with ERDA-6, for about half of the lab studies of MgO at SNL in Albuquerque during the mid-to-late 1990s. Appendix A contains the draft memorandum in which Krumhansl defined GWB, compared it to other standard WIPP brines, and developed a recipe for it.

This report describes the independent verification of the calculations that: (1) used the results of Krumhansl et al. (1991) to define an average, intergranular, Salado-Fm. brine, and (2) developed a recipe for this brine. This report describes the establishment of GWB in such a manner that any technically qualified person can reconstruct this work, if necessary.

3 DEFINITION OF GWB

Sampling and chemical analysis of intergranular Salado brines are described in detail by Krumhansl et al. (1991). The raw analytical data used in the following calculations are found in Table 3.1, 3.2, and 3.3 of Krumhansl et al. (1991). These tables are reproduced in the attached spreadsheet (see Appendix B of this report). The data are listed as ions in parts per thousand (ppt), the only exception being Li, which was reported in parts per million (ppm). The first column under each heading contains the raw data, the second column, where applicable, contains the raw data corrected using an internal standard (Krumhansl et al., 1991, p. 11). An exception is the first heading listed as Ca, in which there are three columns present. The second column provides the raw data, whereas the third column lists the corrected data. Zeros present in any column represent "no data."

All calculations were reproduced using the Microsoft EXCEL 2000 spreadsheet program running Windows 2000 (see Appendix B of this report). Krumhansl recorded the original analyte concentrations and computed charge balances using EXCEL 97. The spreadsheet is entitled "WEEPSNEW.XLS" and contains both the original data from Krumhansl's 1999 draft memo and the verification calculations by A. C. Snider (ACS).

The EXCEL file is divided into six sheets (Appendix B). The first three sheets, labeled Table 3.1, Table, 3.2, and Table 3.3, are the original data from Krumhansl. The following three sheets are the recreated calculations by Snider. Each sheet tab has the initials ACS in parentheses. Sheet "Table 3.1" includes the original data and samples taken directly from Krumhansl's 1991 report. Averages of major cations are under columns P, Q, R, and S, and calculated charge balances for uncorrected and corrected data are under columns T and U respectively. Sheet "Table 3.2" record samples and original data found in Krumhansl's 1991 report, uncorrected and corrected charge balances are under columns Q and R respectively. Sheet "Table 3.3" includes all data from Kurmhansl's 1991 report. Uncorrected and corrected charge balances are under columns Q and R respectively. Sheet "Ions & avg (ACS)" displays all original data copied from the previous three sheets with labels in row 1 indicating which data is raw and which data has been corrected using an internal standard. Row 80 and below present the average and standard deviation for each element concentration. All data is presented in ppt, exception being Li, which is measured in ppm. Sheet "Molarity and salt wt calcs (ACS)" displays the calculations and results used to recreate the brine molarity for each element and the amount of salt needed to mix 1 kg GWB. The initial part of the spreadsheet (rows 1–13) converts average element concentrations to molar and millimolar concentrations (columns E and F respectively). The middle portion of the sheet (rows 15-36) tracks the amount of Na and Cl moles needed to achieve and exact charge balance, Cl being the adjustable parameter. The final third of the sheet displays the salts used in the brine recipe and the calculations, which determined the correct amounts of salt needed. Column E is the amount calculated from the original Salado samples, whereas column F is the actual amount of salt needed in order to dissolve all the salts completely in 1 kg GWB.

The data used for Snider's calculation were a combination of Krumhansl's corrected data, when available, and Krumhnsl's original raw data. Averages, reported in ppt, were converted to moles per liter, assuming a brine density of 1.2 kg/L. The results are presented in Table 1.

Table 2. Composition of GWB

Element	Concentration (ppt)	Standard Deviation	Concentration (M)
Li^+	0.025	0.004	0.0044
$B(OH)_3(aq)$	1.42	0.21	0.157
Na^+	67.6	11.5	3.53
Mg^{2+}	20.6	4.2	1.02
K^+	15.2	2.3	0.465
Ca^{2+}	0.46	0.21	0.014
SO_4^{2-}	14.2	2.0	0.177
Br^-	1.8	0.5	0.027
Cl^-	173	16	5.87

4 DEVELOPMENT OF A RECIPE FOR GWB

Once the molar concentrations were defined, a GWB recipe was formulated. The ion averages did not need to be further modified, all ions charge balanced within the standard deviations. However, the charge balance reported by Krumhansl (Appendix A) was miscalculated, the ratio of cationic charges to anionic charges is 1.03. To achieve an exact charge balance, Cl concentration was designated as the adjustable parameter.

The following salts were used to account for all the chemical components used to define GWB (see Table 2 above):

- lithium ($LiCl$),
- borate ($Na_2B_4O_7 \cdot 10H_2O$),
- sodium ($NaCl$),
- magnesium ($MgCl_2 \cdot 6H_2O$)
- potassium (KCl),
- calcium ($CaCl_2 \cdot H_2O$),
- sulfate (Na_2SO_4), and
- bromide ($NaBr$).

To determine the quantity of salt in grams of each chemical component to be added to the solution, per kg solution, a running balance of Na^+ and Cl^- was tabulated first. A Na^+ inventory was kept in the following manner using the Na^+ salts:

- SO_4^{2-}: added as **X** moles of Na_2SO_4 per kg of solvent; **Y** moles of Na remaining per kg of solvent = (total moles per kg of Na needed) – 2(**X**).
- Br^-: added as **Z** moles of NaBr per kg of solvent; **U** moles per kg of Na remaining per kg of solvent = **Y** – **Z**
- B: added as **V/4** moles of $Na_2B_4O_7 \cdot 10H_2O$ per kg of solvent; **W** moles of Na per kg of solvent remaining to be added as NaCl= **U-V/2**

The Cl^- balance was determined in a similar manner using Cl^- salts:

- Ca^{2+}: added as **A** moles of $CaCl_2 \cdot 2H_2O$ per kg of solvent; **B** moles of Cl^- remaining per kg of solvent = (total moles per kg of Cl^- needed) - 2(**A**)

- Li^+: added as **C** moles of LiCl per kg solvent; **D** moles of Cl^- remaining per kg of solvent = **B** – **C**

- Mg^{2+}: added as **E** moles of $MgCl_2 \cdot 6H_2O$ per kg of solvent; **F** moles of Cl^- remaining per kg of solvent = **D** – 2(**E**)

- K^+: added as **G** moles of KCl per kg of solvent; **H** moles of Cl^- remaining per kg of solvent = **F** – **G**

- Na^+: added as **W** moles of NaCl per kg of solvent; moles of Cl^- remaining per kg of solvent = **H-W**

Chloride was designated the adjustable parameter, therefore the chloride added to the brine mixture contains ~4.5% less chloride than originally calculated. After the Na^+ and Cl^- balance was attained, the weight in grams of each salt for 1 kg of GWB brine was calculated.

However, Krumhansl discovered that an additional 15 g of deionized water was needed for complete dissolution to occur. Thus, to actually prepare 1 kg of GWB, the calculated grams of salt and water must be multiplied by 1000 g/1015 g, which equals 0.9852. Table 3 gives the masses of salts needed to prepare 1 kg of GWB to obtain the composition in Table 2 and the weights of salts after multiplication by the correction factor of 0.9852.

Table 3. Recipe for 1 kg of GWB

Salt	Formula Wt (g/mol)	Quantity Calculated to Synthesize 1 kg of GWB with the Composition Shown in Table 2 (g)	Quantity Required to Synthesize 1 kg of GWB after Addition of 15 g of H_2O and Multiplication by 0.9852 (g)
H_2O	18.016	612	617[1]
LiCl	42.391	0.15	0.15
$Na_2B_4O_7 \cdot 10H_2O$	381.38	12.5	12.3
NaCl	58.440	150	147
$MgCl_2 \cdot 6H_2O$	203.31	172	170
KCl	74.550	28.9	28.5
$CaCl_2 \cdot 2H_2O$	147.01	1.7	1.7
Na_2SO_4	142.04	21.0	20.7
NaBr	102.89	2.3	2.2

1. 617 g = (612 g + 15 g) × 0.9852.

Table 4 compares the composition of GWB from Table 2 and that synthesized with the quantities of salts obtained after addition of 15 g of H_2O and multiplication by 0.9852.

Table 4. Comparison of the Composition of GWB from Table 2 and Synthetic GWB (see text).

Element	Concentration from Table 2 (M)	Concentration after Addition of 15 g of H_2O and Multiplication by 0.9852 (M)
Li^+	0.0044	0.0043
$B(OH)_3(aq)$	0.157	0.155
Na^+	3.53	3.48
Mg^{2+}	1.02	1.00
K^+	0.465	0.458
Ca^{2+}	0.014	0.014
SO_4^{2-}	0.177	0.175
Br^-	0.027	0.026
Cl^-	5.87	5.51[1]

1. The change in concentration of Cl^- is greater than those for other elements because it was the parameter adjusted to achieve charge balance.

To prepare GWB, we follow the procedure described by Robinson (1996) without any additional modification of the recipe.

5 REFERENCES

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APPENDIX A: "DEFINITION OF GW BRINE," BY J.L. KRUMAHNSL

Date: May 1, 1999

To: Hans Papenguth, 6832

From: Jim Krumhansl, 6118

Subject: Definition of GW Brine - ***DRAFT!***

Introduction:

Early MgO studies showed that when the two traditional WIPP test brines (e.g. Castile and the SST or Brine A) were used the results were often quite different. In particular, the difference in Mg concentration seems to be a critical variable. Current PA scenarios also require evaluating the possibility that brines indigenous to the Salado may enter the repository in significant quantities. Thus, there would be considerable benefit from developing a test fluid that was directly traceable to brines sampled in the Salado. Over the years much effort has been devoted to sampling Salado brines and, generally, these fluids are not a close match to either SST or Castile brine

Methodology

A comprehensive analysis of weep fluids was tabulated by Krumhansl, Kimball and Stein, (1991, Tables 3.1-3.3 (note: Li values were incorrectly reported as ppt; they should be ppm.). This provides a basis for defining a generic weep fluid ("GW Brine") for use in MgO backfill tests. Cation analyses were done on a Spectraspan VII DCP. For all cations the raw analysis is reported and for some of the key components the raw data was corrected using an internal standard procedure (SAND90-0584, p. 11). This correction resulted in a slightly better charge balance so these figures were used in formulating the recipe for GW brine presented below. Sulfate and bromide analyses were done with a Dionix 2000i ion chromatograph and chloride was analyzed with a Buchler chloridometer. Table 1 presents averages and standard deviations for the analyses summarized in SAND90-0584, along with the final as-mixed composition of the GW brine.

For comparison (Table 2), these averaged values are presented with a variety of standard WIPP test brines summarized by Molecke (1990). Of these, the artificial Salado brine termed PAB-1 is the best match (Table 2) but apparently it has not been widely used in WIPP laboratory tests.

Computation performed using an EXCEL 97-SR10 spreadsheet titled WEEPSNEW.XLS that resides in Jim Krumhansl's computer.

Table 1. Averages and Standard Deviations, from Tables 3.1 - 3.3 of SAND90-0584

Component	Raw	With Internal Standard
	ppt	ppt
Ca (ppt)	0.46 ± 0.35	0.46 ± 0.21
B (ppt)	1.42 ± 0.21	Not Performed
Li (ppm)*	25.3 ± 4.1	Not Performed
Mg (ppt)	20.5 ± 4.5	20.6 ± 4.2
K (ppt)	15.2 ± 2.3	15.2 ± 2.3
Na (ppt)	66.0 ± 10.4	67.6 ± 11.5
Cl (ppt)	173 ± 16	Not Performed
$SO_4^=$ (ppt)	14.2 ± 2.0	Not Performed
Br (ppt)	1.77 ± 0.45	Not Performed
Charge balance	+/- = 0.955	+/- = 0.969

Table 2. Chemistry (moles/liter) of Different WIPP Brines (see Appendix Table A-1 for conversions).

Component	GW	PAB-1	Brine A	Castile
B (mM)	158	152	20	92
Ca (mM)	14	10	20	8.7
K (mM)	467	500	770	74
Mg (M)	1.02	1.00	1.44	0.066
Na (M)	3.53	3.9	1.83	6.00
Br (mM)	26.6	13	10	6.4
Cl (M)	5.86	6.04	5.35	5.02
$SO_4^=$ (mM)	177	160	40	190
S.G.	1.2*	1.22	1.2	--

*Assumed value, needed for converting from g/kg to moles/l.

Brine Recipe

It is a fortunate coincidence that the averages of all these brines produces a mix that, within the standard deviations of the averages, is essentially neutral. Thus, these averages can be used with little further modification to develop a recipe for the standard GW brine. To actually mix a brine it is, of course, necessary to have an exact charge balance. To achieve this Cl was left as the adjustable parameter. Doing this resulted in a brine that contained 4.39% less chloride than the computed average in Table 1. Appendix Table A-2 records the computations needed to arrive at this figure. In doing so it was necessary to determine what salts would be used to provide the different components and also account for the amounts of the counter-ions (Na or Cl) that would be added along with the desired components. Table A-3, and the "as analyzed" column of Table 3, records the amounts of salts needed to prepare the brine mixture developed so far.

However, when the attempt was made to mix this brine a final problem was encountered; the mix was not fully soluble. Thus, it proved necessary to add an additional

15 grams of water, which increased the water added from the 611.764 grams derived from the exact recipe (Table A 3) to 626.764g. Thus, to actually prepare 1 kg of GW brine the "as analyzed" amounts of salts and water have to be multiplied by 1000/1015 = 0.985222 - to produce the "as mixed" recipe for 1 kg of brine. Then, finally, the "per liter" recipe values were obtained by multiplying by the assumed specific gravity of the brine, 1.2

Table 3. Recipe for Generic Weep ("GW") Brine

Component	Salt Added	per kg as-analyzed	per kg as-mixed	per liter# (s.g. = 1.2)
1. Sulfate	Na_2SO_4	21.022 g	20.711 g	24.853 g
2. Bromide	NaBr	2.284 g	2.250 g	2.700 g
3. Boron	$Na_2B_4O_7.10H_2O$	12.490 g	12.305 g	14.766 g
4. Sodium	NaCl	149.390 g	147.184 g	176.619 g
5. Potassium	KCl	29.004 g	28.575 g	34.290 g
6. Magnesium	$MgCl_2.6H_2O$	172.203g	169.658 g	203.590 g
7. Lithium	LiCl	0.155 g	0.153 g	0.183 g
8. Calcium	$CaCl_2.2H_2O$	1.688 g	1.663 g	1.996 g
9. Water	Deionized H_2O	611.764 g	617.501 g	741.003 g
Total Weight		1000.00 g	1000.00 g	1,200 g
Total Volume		833.33 ml	833.33 ml	1000 ml

References

Krumhansl, J.L., K.M. Kimball, and C.L. Stein. 1991. *Intergranular Fluid Compositions from the Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico.* SAND90-0584. Albuquerque, NM: Sandia National Laboratories.

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Appendix 1. Calculations Used to Develop the GW Brine Recipe

Table A-1 Conversion of Analytic Results to Moles

Element	g/kg Brine (Table 1)	Formula Weight	Moles/kg (s.g.=1.2)	Moles/l
Ca	0.46	40.08	0.0115	0.0138
B	1.42	10.811	0.131	0.158
Li	25.3E-3	6.939	3.65E-3	4.38E-3
Mg	20.6	24.312	0.847	1.02
K	15.2	39.0983	0.389	0.467
Na	67.6	22.9898	2.94	3.53
[Cl]	[173]	35.453	[4.88]	[5.86]
$SO_4^{=}$	14.2	96.0616	0.148	0.177
Br	1.77	79.903	0.0222	0.0266

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Table A-2. Running Na and Cl Balances

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Na Balance

Total Na inventory is 2.94 moles per kg.

$SO_4^=$ added as 0.148 moles of Na_2SO_4.
Na balance: 2.94 - 2 x 0.148 = 2.6440 moles Na remain per kg of brine as analyzed.

Br added as 0.0222 moles of NaBr
Na balance: 2.6440 - 0.0222 = 2.6218 moles Na remain per kg of brine as analyzed.

B added as (0.131)/4 = 0.0328 moles of $Na_2B_4O_9.10H_2O$.
Na balance: 2.6218 - (0.131)/2 = 2.5563 (i.e. 2.56) moles Na remain to be added as NaCl per kg of brine as analyzed.

Cl Balance

Ca added as 0.0115 moles of $CaCl_2.2H_2O$
Cl balance: 2 x 0.0115 = 0.0230 moles Cl

Li added as 3.65E-3 moles of LiCl
Cl balance: 0.00365 moles Cl

Mg added as 0.847 moles of $MgCl_2.6H_2O$
Cl balance 2 x 0.847 = 1.694 moles Cl

K added as 0.389 moles of KCl
Cl balance 0.389 moles Cl

Na added as 2.5563 moles of NaCl
Cl Balance 2.5563 moles Cl

Total added per kilogram of brine: 4.66595 moles Cl

This amount of Cl is slightly less than the average Cl values presented in Tables 1, 2 and A-1.

[(100)(4.88 - 4.66595)/4.88] = 4.39% less Cl

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Table A-3. Weights of salts added to make 1 kg of brine

(0.148 moles of Na_2SO_4) x 142.04 g/mole = 21.022 g Na_2SO_4

(0.0222 moles of NaBr) x 102.90 g/mole = 2.284 g NaBr

(0.03275 moles of $Na_2B_4O_7.10H_2O$) x 381.37 g/m = 12.490 g Borax

(0.0115 moles of $CaCl_2.2H_2O$) x 147.02 g/m = 1.688 g $CaCl_2.2H_2O$

(3.65E-3 moles of LiCl) x 42.39 g/mole = 0.155 g LiCl

(0.847 moles of $MgCl_2.6H_2O$) x 203.31 g/m = 172.203 g $MgCl_2.6H_2O$

(0.389 moles of KCl) x 74.56 g/mole = 29.004 g KCl

(2.5563 moles of NaCl) x 58.44 g/mole = 149.390 g NaCl
Total weight of salts: 388.236 g
Remaining Water: 611.764 g

APPENDIX B: "WEEPSNEW.XLS"

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	Sample	Ca			B	Li	Mg		K		Na		Cl	SO_4	Br	Av Ca	Av Mg	K Av	Na Av	chbal-uncr	chbal-corr
2	21A1	2.80	2.90	nd	nd	nd	32.0	38.7	5.2	6.3	18.1	20.9	143	20.2	3.5	#VALUE!	35.35	5.75	19.5	0.805895636	0.961202112
3	26A2	1.70	1.60	1.7	1.41	30	20.7	20.0	16.2	16.2	82.1	84.2	180	15.2	1.5	1.67	20.35	16.2	83.15	1.065632869	1.073589138
4	27A3	0.73	0.70	0.69	1.34	25	17.5	16.9	15.3	15.6	71.8	77.3	175	13.5	1.4	0.71	17.2	15.45	74.55	0.95296701	0.991674246
5	28A4	0.66	0.56	0.61	1.57	27	18.5	18.2	16.2	16.8	71.3	78.2	172	13.7	1.4	0.61	18.35	16.5	74.75	0.982692328	1.040827021
6	29A5	0.56	0.58	0.58	1.32	25	18.2	18.1	15.4	15.6	68.9	75.3	173	14.3	1.3	0.57	18.15	15.5	72.1	0.946631401	1.000127416
7	30A6	0.36	0.44	0.46	1.44	25	17.1	17.2	15.3	15.8	66.7	72.2	169	13.5	1.4	0.42	17.15	15.55	69.45	0.931959335	0.983253668
8	3B1	0.31	0.35	0.37	1.48	24	18.2	17.3	15.8	15.9	70.3	73.1	171	13.0	1.3	0.34	17.75	15.85	71.7	0.973768789	0.983897978
9	16B2	0.21	0.31	0.33	1.41	23	17.4	16.9	15.6	15.1	69.0	72.4	167	13.1	1.4	0.28	17.15	15.35	70.7	0.969200764	0.987654264
10	19B3	0.38	0.40	0.44	1.37	23	17.7	16.9	15.2	14.5	67.7	69.2	166	13.7	1.4	0.41	17.3	14.85	68.45	0.964711954	0.961471118
11	20B4	0.29	0.39	0.44	1.36	25	18.7	17.1	15.5	13.9	70.3	67.7	167	14.3	3.7	0.37	17.9	14.7	69	0.991516289	0.934734952
12	24B5	0.24	0.28	0.32	1.29	23	18.0	17.0	14.9	14.2	67.1	67.6	164	13.1	1.3	0.28	17.5	14.55	67.35	0.975416029	0.959729313
13	22B6	0.35	0.44	0.47	1.42	26	18.9	17.6	16.1	14.8	69.8	68.5	169	13.9	1.4	0.42	18.25	15.45	69.15	0.990217175	0.951297965
14	2C1	0.41	0.46	0.46	1.46	26	19.7	18.3	16.4	16.0	69.4	69.9	168	14.0	1.4	0.44	19	16.2	69.65	1.006650206	0.98636416
15	4C2	0.26	0.28	0.31	1.44	23	18.5	17.4	15.9	15.5	69.4	71.5	167	13.3	1.5	0.28	17.95	15.7	70.45	0.990935782	0.98952413
16	14C3	0.20	0.35	0.38	1.52	24	18.6	17.7	16.6	15.8	73.4	74.1	168	13.2	1.5	0.31	18.15	16.2	73.75	1.026103911	1.012578116
17	15C4	0.23	0.37	0.40	1.41	24	18.7	17.8	16.1	15.2	71.3	71.8	168	13.1	1.4	0.33	18.25	15.65	71.55	1.008058892	0.992383249
18	25C5	0.39	0.45	0.50	1.24	28	18.8	18.2	15.0	14.4	69.3	70.8	169	13.6	1.4	0.45	18.5	14.7	70.05	0.980071268	0.980382755
19	23C6	0.25	0.32	0.38	1.33	24	18.8	16.8	15.7	13.8	69.2	65.5	169	13.4	1.3	0.32	17.8	14.75	67.35	0.98251584	0.908620867
20	5D1	0.09	0.23	0.24	1.77	36	28.0	26.7	22.0	21.2	55.2	55.1	176	18.5	2.1	0.19	27.35	21.6	55.15	0.981832628	0.956990767
21	6D2	nd	0.31	nd	nd	nd	nd	18.7	0.0	15.0	nd	68.4	168	12.7	1.8	#VALUE!	#VALUE!	7.5	#VALUE!	dud	0.977436361
22	1D3	0.38	0.40	0.42	1.32	23	18.8	17.6	15.3	14.8	69.4	70.0	166	14.9	1.9	0.40	18.2	15.05	69.7	0.991989344	0.975425526
23	9D4	0.37	0.40	0.41	1.29	22	19.3	18.7	14.9	15.2	66.6	72.4	166	13.9	1.4	0.39	19	15.05	69.5	0.979160343	1.021700883
24	7D5	0.29	0.42	0.44	1.12	23	21.0	20.2	15.0	14.7	68.1	69.7	167	15.0	1.3	0.38	20.6	14.85	68.9	1.010874347	1.00947214
25	8D6	0.57	0.64	0.67	1.03	24	20.2	21.2	13.4	14.1	65.4	68.9	172	15.2	1.4	0.63	20.7	13.75	67.15	0.941215699	0.989880254
26	18E1	0.25	0.30	0.33	1.52	24	17.3	17.0	15.4	15.2	68.1	72.0	169	13.1	1.3	0.29	17.15	15.3	70.05	0.948147386	0.975994103
27	17E2	0.34	0.42	0.46	1.46	23	18.0	17.8	15.3	15.4	67.6	72.0	168	13.8	1.4	0.41	17.9	15.35	69.8	0.958258973	0.993312495
28	13E3	0.32	0.38	0.42	1.46	22	18.2	17.2	16.5	15.9	71.5	73.1	169	13.6	1.4	0.37	17.7	16.2	72.3	0.996093256	0.99059923
29	12E4	0.39	0.47	0.47	1.47	22	18.1	17.4	16.3	16.1	71.4	74.3	169	13.1	1.6	0.44	17.75	16.2	72.85	0.995042329	1.007416354
30	11E5	0.46	0.51	0.53	1.31	22	18.1	18.1	15.3	16.3	67.7	74.8	171	13.6	1.2	0.50	18.1	15.8	71.25	0.947006642	1.012425894
31	10E6	0.68	0.74	0.75	2.00	35	25.2	26.1	22.1	23.6	107.3	115.7	245	18.2	2	0.72	25.65	22.85	111.5	1.003728302	1.069320936
32																#VALUE!				0.975803266	0.98930958
33	Table 3.1: Weeps; Array #1 (parts per thousand)																			0.043061237	0.034368668

Table 3.1

Table 3.2

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Sample	Ca			B	Li	Mg		K		Na		Cl	SO_4	Br			
2	53AA1	0.32	0.31	0.32	1.52	24	18.7	18.3	15.7	15.7	68.3	69.2	170	13.0	2.2		0.96779	0.969113
3	55AA2	0.29	0.27	0.29	1.49	25	17.9	17.8	15.2	15.2	66.1	67.6	174	11.7	1.7		0.91887	0.930084
4	56AA3	0.35	0.34	0.33	1.49	24	18.4	18.3	15.5	15.7	68.7	70.9	169	12.7	2.0		0.972709	0.991115
5	57AA4	0.48	0.42	0.41	1.59	25	19.2	19.6	16.4	17.2	72.9	77.9	171	16.2	1.9		1.001845	1.054661
6	58AA5	1.0	0.92	1.0	2.44	44	34.8	35.2	25.5	27.0	111.2	117.9	283	24.0	3.3		0.985918	1.028935
7	59AA6	0.56	0.49	0.57	1.57	24	17.8	17.6	15.6	15.7	67.3	67.5	173	13.0	2.1		0.930742	0.930413
8	75BB1	0.22	0.22	0.26	1.29	20	1.94	19.3	14.1	14.3	64.3	65.8	167	12.6	1.8		0.666738	0.966701
9	74BB2	0.30	0.28	0.32	1.49	23	19.9	19.8	14.7	15.0	68.8	70.7	170	13.6	1.8		0.98465	1.000937
10	77BB3	0.30	0.30	0.33	1.33	23	20.7	20.1	14.9	14.8	64.7	65.5	168	13.4	1.8		0.975374	0.971977
11	80BB4	0.35	0.42	0.47	1.07	22	22.8	22.4	13.7	13.5	61.4	62.2	172	14.1	1.9		0.951944	0.950644
12	79BB5	0.12	0.23	0.26	1.27	20	18.7	18.8	14.6	14.6	65.4	67.3	173	12.6	1.7		0.923904	0.940439
13	61BB6	0.22	0.21	nd	nd	nd	18.1	18.1	13.7	13.9	61.6	64.2	165	11.4	1.7		0.921878	0.946039
14	78CC1	0.23	0.28	0.31	1.37	22	19.4	19.4	15.1	15.2	67.1	69.1	176	13.3	1.7		0.934439	0.95098
15	76CC2	0.24	0.29	0.33	1.41	22	18.2	18.5	15.3	15.7	69.0	72.4	168	13.6	1.8		0.972774	1.008515
16	74CC3	0.33	0.29	0.30	1.33	22	18.3	18.1	15.6	15.8	66.3	68.9	168	13.0	1.8		0.955013	0.975629
17	68CC4	0.33	0.32	0.37	1.46	23	17.9	17.5	14.9	14.6	67.3	67.3	176	13.7	1.7		0.910637	0.903034
18	62CC5	0.33	0.31	0.25	1.31	21	18.9	18.4	15.4	15.1	66.5	67.4	184	13.4	1.8		0.884877	0.8833
19	63CC6	0.46	0.55	0.60	1.46	23	17.3	18.0	15.3	15.8	68.7	73.0	170	14.7	1.8		0.943278	0.992636
20	69DD2	0.23	0.27	0.29	1.45	22	18.8	17.7	15.1	14.4	66.0	65.2	167	13.1	1.9		0.962613	0.933618
21	72DD3	0.57	0.54	0.58	1.11	23	20.4	20.5	14.2	14.3	64.3	66.8	171	14.2	1.9		0.946594	0.970124
22	65DD4	0.21	0.28	0.31	1.46	23	19.5	20.0	15.1	15.6	65.0	67.8	174	13.0	2.2		0.928627	0.961704
23	64DD5	0.36	0.47	0.51	1.05	21	20.6	20.5	12.9	12.9	60.0	61.7	172	14.2	1.7		0.901721	0.913373
24	66DD6	0.56	0.62	0.67	1.24	23	18.5	18.9	14.8	15.1	68.3	70.7	171	14.9	2.1		0.950632	0.978145
25																	0.934503	0.963136
26																	0.06488	0.039894

Table 3.3

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Sample	Ca			B	Li	Mg		K		Na		Cl	SO_4	Br			
2	49A1	0.43	0.52	0.59	1.44	27	22.5	22.7	14.6	14.6	63.0	62.3	175	14.4	1.8		0.949724	0.946209
3	50A2	0.43	0.48	0.54	1.31	29	21.6	22.1	13.3	13.8	60.3	61.9	171	14.1	1.7		0.927899	0.95145
4	51A3	0.27	0.42	0.43	1.42	25	21.3	21.8	13.9	14.0	61.8	61.7	170	13.2	1.6		0.946968	0.953226
5	52A4	0.19	0.33	0.33	1.44	30	21.3	22.0	13.8	14.1	61.8	61.7	173	12.9	1.8		0.930934	0.941362
6	47A5	0.21	0.33	0.32	1.50	26	21.1	21.6	13.8	14.0	62.4	63.0	174	12.5	1.8		0.929117	0.9419
7	45A6	0.45	0.54	0.61	1.44	26	23.2	23.3	14.7	14.7	62.5	61.7	177	14.9	1.8		0.945176	0.939344
8	37B1	0.05	0.20	0.22	1.82	29	34.1	32.1	17.7	16.2	44.3	44.6	177	17.8	2.5		0.963695	0.927117
9	38B2	0.53	0.76	0.80	1.35	27	24.3	25.1	15.2	14.9	63.8	64.4	184	15.9	1.9		0.938584	0.951706
10	41B3	0.39	0.66	0.65	1.43	34	23.3	23.9	15.3	14.9	61.6	61.6	178	14.0	1.9		0.941699	0.946507
11	43B4	0.35	0.53	0.52	1.79	36	37.0	35.3	19.1	17.8	46.8	48.5	191	20.8	2.8		0.956212	0.937745
12	42B5	0.51	0.64	0.72	1.36	28	24.4	24.1	15.7	15.4	62.2	61.5	178	15.2	1.9		0.960615	0.947692
13	46B6	0.13	0.25	0.27	1.36	27	23.2	23.2	14.3	14.2	59.6	59.3	172	13.0	1.9		0.948837	0.944641
14	31C1	0.14	0.31	0.28	1.27	26	22.0	22.4	13.6	13.7	60.1	60.3	169	13.5	1.7		0.945042	0.95208
15	32C2	0.10	0.27	0.26	1.21	21	21.8	22.0	13.3	13.3	59.8	59.8	168	14.4	1.7		0.938925	0.9405
16	33C3	0.11	0.26	0.26	1.26	26	21.9	21.5	13.5	13.5	62.2	62.1	171	14.6	1.7		0.945642	0.936953
17	34C4	0.15	0.27	0.28	1.28	24	22.2	22.1	13.7	13.8	60.2	59.9	169	14.2	1.7		0.946477	0.941618
18	36C5	0.36	0.53	0.58	1.27	23	22.5	22.1	13.8	13.4	62.7	60.8	172	13.4	1.8		0.962641	0.936589
19	40C6	0.09	0.26	0.25	1.30	31	22.3	22.4	13.8	13.6	60.9	59.8	170	13.1	1.8		0.95346	0.943006
20	44D1	0.21	0.32	0.33	1.46	23	20.6	20.8	14.0	14.1	63.0	63.5	170	13.2	1.6		0.945374	0.952303
21	48D2	0.43	0.54	0.55	1.33	28	20.9	21.0	14.0	14.1	64.5	64.2	171	14.5	1.6		0.954965	0.953459
22	35D3	0.35	0.55	0.54	1.41	22	20.9	20.9	14.4	14.2	63.6	63.3	171	14.2	1.6		0.950429	0.944953
23	39D4	0.25	0.55	0.51	1.34	27	21.2	21.8	14.8	14.7	63.1	63.1	171	14.3	1.7		0.952512	0.958702
24	60D5	0.39	0.57	0.51	1.81	31	22.5	23.0	15.9	15.9	60.8	62.2	176	14.2	1.9		0.933942	0.951551
25	54D6	0.42	0.60	0.57	1.42	25	20.5	20.9	14.0	14.1	63.7	64.0	172	13.8	1.6		0.939817	0.947479
26																	0.946195	0.945337
27																	0.00995	0.007139
28	Sample	Ca			B	Li	Mg		K		Na		Cl	SO_4	Br			
29	21A1	2.80	2.90	nd	nd	nd	32.0	38.7	5.2	6.3	18.1	20.9	143	20.2	3.5			
30	26A2	1.70	1.60	1.7	1.41	30	20.7	20.0	16.2	16.2	82.1	84.2	180	15.2	1.5			
31	27A3	0.73	0.70	0.69	1.34	25	17.5	16.9	15.3	15.6	71.8	77.3	175	13.5	1.4			
32	28A4	0.66	0.56	0.61	1.57	27	18.5	18.2	16.2	16.8	71.3	78.2	172	13.7	1.4			
33	29A5	0.56	0.58	0.58	1.32	25	18.2	18.1	15.4	15.6	68.9	75.3	173	14.3	1.3			
34	30A6	0.36	0.44	0.46	1.44	25	17.1	17.2	15.3	15.8	66.7	72.2	169	13.5	1.4			
35	3B1	0.31	0.35	0.37	1.48	24	18.2	17.3	15.8	15.9	70.3	73.1	171	13.0	1.3			
36	16B2	0.21	0.31	0.33	1.41	23	17.4	16.9	15.6	15.1	69.0	72.4	167	13.1	1.4			
37	19B3	0.38	0.40	0.44	1.37	23	17.7	16.9	15.2	14.5	67.7	69.2	166	13.7	1.4			
38	20B4	0.29	0.39	0.44	1.36	25	18.7	17.1	15.5	13.9	70.3	67.7	167	14.3	3.7			
39	24B5	0.24	0.28	0.32	1.29	23	18.0	17.0	14.9	14.2	67.1	67.6	164	13.1	1.3			
40	22B6	0.35	0.44	0.47	1.42	26	18.9	17.6	16.1	14.8	69.8	68.5	169	13.9	1.4			
41	2C1	0.41	0.46	0.46	1.46	26	19.7	18.3	16.4	16.0	69.4	69.9	168	14.0	1.4			
42	4C2	0.26	0.28	0.31	1.44	23	18.5	17.4	15.9	15.5	69.4	71.5	167	13.3	1.5			
43	14C3	0.20	0.35	0.38	1.52	24	18.6	17.7	16.6	15.8	73.4	74.1	168	13.2	1.4			
44	15C4	0.23	0.37	0.40	1.41	24	18.7	17.8	16.1	15.2	71.3	71.8	168	13.1	1.4			
45	25C5	0.39	0.45	0.50	1.24	28	18.8	18.2	15.0	14.4	69.3	70.8	169	13.6	1.4			

Table 3.3 (continued)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
46	23C6	0.25	0.32	0.38	1.33	24	18.8	16.8	15.7	13.8	69.2	65.5	169	13.4	1.3			
47	5D1	0.09	0.23	0.24	1.77	36	28.0	26.7	22.0	21.2	55.2	55.1	176	18.5	2.1			
48	6D2	nd	0.31	nd	nd	nd	nd	18.7	nd	15.0	nf	68.4	168	12.7	1.8			
49	1D3	0.38	0.40	0.42	1.32	23	18.8	17.6	15.3	14.8	69.4	70.0	166	14.9	1.9			
50	9D4	0.37	0.40	0.41	1.29	22	19.3	18.7	14.9	15.2	66.6	72.4	166	13.9	1.4			
51	7D5	0.29	0.42	0.44	1.12	23	21.0	20.2	15.0	14.7	68.1	69.7	167	15.0	1.3			
52	8D6	0.57	0.64	0.67	1.03	24	20.2	21.2	13.4	14.1	65.4	68.9	172	15.2	1.4			
53	18E1	0.25	0.30	0.33	1.52	24	17.3	17.0	15.4	15.2	68.1	72.0	169	13.1	1.3			
54	17E2	0.34	0.42	0.46	1.46	23	18.0	17.8	15.3	15.4	67.6	72.0	168	13.8	1.4			
55	13E3	0.32	0.38	0.42	1.46	22	18.2	17.2	16.5	15.9	71.5	73.1	169	13.6	1.4			
56	12E4	0.39	0.47	0.47	1.47	22	18.1	17.4	16.3	16.1	71.4	74.3	169	13.1	1.6			
57	11E5	0.46	0.51	0.53	1.31	22	18.1	18.1	15.3	16.3	67.7	74.8	171	13.6	1.2			
58	10E6	0.68	0.74	0.75	2.00	35	25.2	26.1	22.1	23.6	107.3	115.7	245	18.2	2			
59	53AA1	0.32	0.31	0.32	1.52	24	18.7	18.3	15.7	15.7	68.3	69.2	170	13.0	2.2			
60	55AA2	0.29	0.27	0.29	1.49	25	17.9	17.8	15.2	15.2	66.1	67.6	174	11.7	1.7			
61	56AA3	0.35	0.34	0.33	1.49	24	18.4	18.3	15.5	15.7	68.7	70.9	169	12.7	2.0			
62	57AA4	0.48	0.42	0.41	1.59	25	19.2	19.6	16.4	17.2	72.9	77.9	171	16.2	1.9			
63	58AA5	1.0	0.92	1.0	2.44	44	34.8	35.2	25.5	27.0	111.2	117.9	283	24.0	3.3			
64	59AA6	0.56	0.49	0.57	1.57	24	17.8	17.6	15.6	15.7	67.3	67.5	173	13.0	2.1			
65	75BB1	0.22	0.22	0.26	1.29	20	1.94	19.3	14.1	14.3	64.3	65.8	167	12.6	1.8			
66	74BB2	0.30	0.28	0.32	1.49	23	19.9	19.8	14.7	15.0	68.8	70.7	170	13.6	1.8			
67	77BB3	0.30	0.30	0.33	1.33	23	20.7	20.1	14.9	14.8	64.7	65.5	168	13.4	1.8			
68	80BB4	0.35	0.42	0.47	1.07	22	22.8	22.4	13.7	13.5	61.4	62.2	172	14.1	1.9			
69	79BB5	0.12	0.23	0.26	1.27	20	18.7	18.8	14.6	14.6	65.4	67.3	173	12.6	1.7			
70	61BB6	0.22	0.21	nd	nd	nd	18.1	18.1	13.7	13.9	61.6	64.2	165	11.4	1.7			
71	78CC1	0.23	0.28	0.31	1.37	22	19.4	19.4	15.1	15.2	67.1	69.1	176	13.3	1.7			
72	76CC2	0.24	0.29	0.33	1.41	22	18.2	18.5	15.3	15.7	69.0	72.4	168	13.6	1.8			
73	74CC3	0.33	0.29	0.30	1.33	22	18.3	18.1	15.6	15.8	66.3	68.9	168	13.0	1.8			
74	68CC4	0.33	0.32	0.37	1.46	23	17.9	17.5	14.9	14.6	67.3	67.3	176	13.7	1.7			
75	62CC5	0.33	0.31	0.25	1.31	21	18.9	18.4	15.4	15.1	66.5	67.4	184	13.4	1.8			
76	63CC6	0.46	0.55	0.60	1.46	23	17.3	18.0	15.3	15.8	68.7	73.0	170	14.7	1.8			
77	69DD2	0.23	0.27	0.29	1.45	22	18.8	17.7	15.1	14.4	66.0	65.2	167	13.1	1.9			
78	72DD3	0.57	0.54	0.58	1.11	23	20.4	20.5	14.2	14.3	64.3	66.8	171	14.2	1.9			
79	65DD4	0.21	0.28	0.31	1.46	23	19.5	20.0	15.1	15.6	65.0	67.8	174	13.0	2.2			
80	64DD5	0.36	0.47	0.51	1.05	21	20.6	20.5	12.9	12.9	60.0	61.7	172	14.2	1.7			
81	66DD6	0.56	0.62	0.67	1.24	23	18.5	18.9	14.8	15.1	68.3	70.7	171	14.9	2.1			
82	49A1	0.43	0.52	0.59	1.44	27	22.5	22.7	14.6	14.6	63.0	62.3	175	14.4	1.8			
83	50A2	0.43	0.48	0.54	1.31	29	21.6	22.1	13.3	13.8	60.3	61.9	171	14.1	1.7			
84	51A3	0.27	0.42	0.43	1.42	25	21.3	21.8	13.9	14.0	61.8	61.7	170	13.2	1.6			
85	52A4	0.19	0.33	0.33	1.44	30	21.3	22.0	13.8	14.1	61.8	61.7	173	12.9	1.8			
86	47A5	0.21	0.33	0.32	1.50	26	21.1	21.6	13.8	14.0	62.4	63.0	174	12.5	1.8			
87	45A6	0.45	0.54	0.61	1.44	26	23.2	23.3	14.7	14.7	62.5	61.7	177	14.9	1.8			
88	37B1	0.05	0.20	0.22	1.82	29	34.1	32.1	17.7	16.2	44.3	44.6	177	17.8	2.5			
89	38B2	0.53	0.76	0.80	1.35	27	24.3	25.1	15.2	14.9	63.8	64.4	184	15.9	1.9			
90	41B3	0.39	0.66	0.65	1.43	34	23.3	23.9	15.3	14.9	61.6	61.6	178	14.0	1.9			

Table 3.3 (continued)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
91	43B4	0.35	0.53	0.52	1.79	36	37.0	35.3	19.1	17.8	46.8	48.5	191	20.8	2.8			
92	42B5	0.51	0.64	0.72	1.36	28	24.4	24.1	15.7	15.4	62.2	61.5	178	15.2	1.9			
93	46B6	0.13	0.25	0.27	1.36	27	23.2	23.2	14.3	14.2	59.6	59.3	172	13.0	1.9			
94	31C1	0.14	0.31	0.28	1.27	26	22.0	22.4	13.6	13.7	60.1	60.3	169	13.5	1.7			
95	32C2	0.10	0.27	0.26	1.21	21	21.8	22.0	13.3	13.3	59.8	59.8	168	14.4	1.7			
96	33C3	0.11	0.26	0.26	1.26	26	21.9	21.5	13.5	13.5	62.2	62.1	171	14.6	1.7			
97	34C4	0.15	0.27	0.28	1.28	24	22.2	22.1	13.7	13.8	60.2	59.9	169	14.2	1.7			
98	36C5	0.36	0.53	0.58	1.27	23	22.5	22.1	13.8	13.4	62.7	60.8	172	13.4	1.8			
99	40C6	0.09	0.26	0.25	1.30	31	22.3	22.4	13.8	13.6	60.9	59.8	170	13.1	1.8			
100	44D1	0.21	0.32	0.33	1.46	23	20.6	20.8	14.0	14.1	63.0	63.5	170	13.2	1.6			
101	48D2	0.43	0.54	0.55	1.33	28	20.9	21.0	14.0	14.1	64.5	64.2	171	14.5	1.6			
102	35D3	0.35	0.55	0.54	1.41	22	20.9	20.9	14.4	14.2	63.6	63.3	171	14.2	1.6			
103	39D4	0.25	0.55	0.51	1.34	27	21.2	21.8	14.8	14.7	63.1	63.1	171	14.3	1.7			
104	60D5	0.39	0.57	0.51	1.81	31	22.5	23.0	15.9	15.9	60.8	62.2	176	14.2	1.9			
105	54D6	0.42	0.60	0.57	1.42	25	20.5	20.9	14.0	14.1	63.7	64.0	172	13.8	1.6			
106	Average	0.39	0.46	0.46	1.42	25.28	20.5	20.6	15.2	15.2	66.0	67.6	173.4	14.2	1.77013		0.955554	0.968851
107	Stdev.	0.36	0.35	0.21	0.21	4.133	4.5	4.2	2.3	2.3	10.4	11.5	16.19	2.0	0.45279			
108	Sample	Ca			B	Li	Mg		K		Na		Cl	SO_4	Br			
109	First																	
110	weeps			Ca				Mg		K		Na	Cl	SO4	Br			
111	1983-1986			2.5				32		12		91.00	191.00	23	1.8			
112				0.5				54		9		32.00	196.00	22	5.3			
113				0.2				40		7		31.00	161.00	18	2			
114				0.2				23		9		62.00	163.00	21	1.3			
115				0.2				16		12		81.00	161.00	25	0.9			
116				0.2				21		8		66.00	163.00	26	1.8			
117				0.4				23		11		67.00	161.00	21	1.4			
118				0.2				38		7		34.00	153.00	17	2.2			
119				0.2				25		9		57.00	165.00	22	1.3			
120				0.2				22		9		66.00	161.00	22	1.2			
121				0.2				29		9		59.00	192.00	25	1.6			
122				0.3				15		13		92.00	177.00	23	0			
123				0.3				29		11		56.00	159.00	19	1.6			
124				0.2				28		9		52.00	168.00	19	1.5			
125				0.2				26		10		61.00	184.00	19	1.4			
126				0.3				24		10		64.00	171.00	26	1.9			
127				0.3				24		10		64.00	172.00	20	1.4			
128				0.3				16		6		79.00	167.00	17	0			
129				0.2				25		11		64.00	164.00	22	1.4			
130				0.1				30		9		49.00	155.00	20	1.7			
131				0.3				30		9		49.00	155.00	20	1.7			
132				0.1				34		10		52.00	177.00	25	2			
133				0.2				36		10		60.00	171.00	22	1.5			
134				0.1				30		9		48.00	170.00	19	1.8			
135				0.1				31		10		49.00	166.00	18	1.7			

Table 3.3 (continued)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
136				0.1				31		9		57.00	170.00	19	1.7			
137				0.1				31		9		49.00	170.00	20	1.7			
138				0.1				30		9		50.00	168.00	19	1.7			
139				0.1				30		9		54.00	172.00	18	1.8			
140				0.1				28		9		55.00	166.00	20	1.5			
141				0.1				29		9		54.00	176.00	19	1.5			
142				0.3				29		9		54.00	174.00	19	1.5			
143				0.2				30		9		55.00	167.00	19	1.6			
144				0.1				29		10		52.00	172.00	20	1.5			
145				0.1				26		10		58.00	164.00	21	1.3			
146				0.2				21		9		66.00	166.00	22	0.8			
147				0.1				29		9		49.00	168.00	19	1.5			
148				0.1				30		9		50.00	158.00	19	1.5			
149				0.1				35		10		44.00	175.00	18	1.9			
150				0.1				44		9		29.00	178.00	40	2.3			
151				0.2				33		9		47.00	173.00	18	1.5			
152				0.2				34		9		49.00	179.00	18	1.5			
153				0.2				29		10		52.00	165.00	17	1.4			
154				0.1				29		9		52.00	165.00	19	1.4			
155				0.1				30		9		52.00	169.00	19	1.4			
156				0.1				25		10		58.00	162.00	20	1.1			
157				0.2				30		9		48.00	164.00	18	1.4			
158				0.1				30		9		50.00	171.00	18	1.4			
159				0				59		6		13.00	201.00	23	3.1			
160				0.1				57		7		16.00	186.00	14	3.1			
161				0.1				25		10		56.00	166.00	21	1.2			
162				0.2				29		13		51.00	166.00	27	1.2			
163				0.2				30		11		48.00	169.00	21	1.5			
164				0.1				45		10		25.00	181.00	24	2.4			
165				0.2				23		8		67.00	157.00	20	1			
166				0.1				50		6		23.00	195.00	15	2.3			
167				0.2				23		8		63.00	162.00	22	1.1			
168				0.1				26		9		55.00	165.00	21	1.5			
169				0.2				34		12		78.00	181.00	21	1.5			
170				0.1				27		9		57.00	175.00	21	1.6			
171				0.2				25		9		62.00	167.00	19	1.4			
172				0.1				28		9		50.00	163.00	21	1.7			
173				0.1				41		8		33.00	171.00	21	2.1			
174				0.1				30		15		47.00	173.00	22	2.2			
175				0.2				24		10		63.00	172.00	20	1.4			
176				0.1				27		9		55.00	163.00	21	1.6			
177				0.1				25		9		62.00	157.00	22	1.5			
178				0.1				50		6		26.00	190.00	16	2.9			
179				0.1				27		9		54.00	160.00	21	1.6			
180				0.1				27		9		53.00	166.00	20	1.5			

Table 3.3 (continued)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
181				0.1				44		7		29.00	177.00	18	2.4			
182				0.1				44		7		28.00	181.00	17	2.4			
183				0.2				30		11		48.00	169.00	20	1.7			
184				0.1				37		9		37.00	171.00	18	1.9			
185				0.2				21		8		64.00	161.00	21	1.1			
186				0.2				24		9		58.00	162.00	20	1.4			
187				0.1				41		8		31.00	174.00	19	2			
188				0.1				53		5		20.00	187.00	20	3.2			
189				0.1				37		10		41.00	171.00	23	1.9			
190				0.2				16		9		75.00	159.00	18	0.8			
191				0.3				15		6		77.00	162.00	15	0.9			
192				0.1				37		9		56.00	160.00	20	1.5			
193				0.1				29		9		56.00	160.00	20	1.5			
194				0.2				26		10		58.00	166.00	21	1.4			
195				0.2				22		8		65.00	160.00	20	1.1			
196				0.2				27		14		56.00	157.00	19	1.7			
197				0.2				22		8		66.00	164.00	21	1.1			
198				0.1				45		9		26.00	181.00	14	2.8			
199				0.2				18		8		70.00	159.00	20	1			
200				0.1				32		9		48.00	161.00	20	1.7			
201				0.1				43		7		28.00	181.00	18	2.2			
202				0.2				18		9		71.00	160.00	20	1			
203				0.2				18		9		72.00	159.00	21	0.9			
204				0.2				27		8		53.00	161.00	25	1.5			
205				0.2				44		7		26.00	177.00	17	2.4			
206				0.2				17		11		70.00	159.00	21	0.9			
207				0.2				21		9		66.00	167.00	21	1.1			
208				0.3				43		7		38.00	186.00	18	0.9			
209				0.1				43		8		34.00	180.00	17	0.7			
210				0.1				27		10		55.00	165.00	21	0.9			
211				0.1				34		7		28.00	171.00	21	1.1			
212				0.1				45		7		28.00	181.00	18	0.9			
213				0.4				13		9		80.00	152.00	26	0.9			
214				0.1				42		7		33.00	177.00	17	2			
215				0.1				42		7		30.00	178.00	20	0.9			
216				0.1				42		8		32.00	180.00	19	0.9			
217				0.2				28		10		54.00	167.00	21	0.9			
218				0.1				31		9		49.00	168.00	20	0.9			
219				0.1				38		10		40.00	177.00	23	1.3			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1				Raw	Correct	Raw	Raw	Raw	Correct	Raw	Correct	Raw	Correct	Raw	Raw	Raw
2		Sample	Ca			B	Li	Mg		K		Na		Cl	SO_4	Br
3		21A1	2.80	2.90	0	0	0	32.0	38.7	5.2	6.3	18.1	20.9	143	20.2	3.5
4		26A2	1.70	1.60	1.7	1.41	30	20.7	20.0	16.2	16.2	82.1	84.2	180	15.2	1.5
5		27A3	0.73	0.70	0.69	1.34	25	17.5	16.9	15.3	15.6	71.8	77.3	175	13.5	1.4
6		28A4	0.66	0.56	0.61	1.57	27	18.5	18.2	16.2	16.8	71.3	78.2	172	13.7	1.4
7		29A5	0.56	0.58	0.58	1.32	25	18.2	18.1	15.4	15.6	68.9	75.3	173	14.3	1.3
8		30A6	0.36	0.44	0.46	1.44	25	17.1	17.2	15.3	15.8	66.7	72.2	169	13.5	1.4
9		3B1	0.31	0.35	0.37	1.48	24	18.2	17.3	15.8	15.9	70.3	73.1	171	13.0	1.3
10		16B2	0.21	0.31	0.33	1.41	23	17.4	16.9	15.6	15.1	69.0	72.4	167	13.1	1.4
11		19B3	0.38	0.40	0.44	1.37	23	17.7	16.9	15.2	14.5	67.7	69.2	166	13.7	1.4
12		20B4	0.29	0.39	0.44	1.36	25	18.7	17.1	15.5	13.9	70.3	67.7	167	14.3	3.7
13		24B5	0.24	0.28	0.32	1.29	23	18.0	17.0	14.9	14.2	67.1	67.6	164	13.1	1.3
14		22B6	0.35	0.44	0.47	1.42	26	18.9	17.6	16.1	14.8	69.8	68.5	169	13.9	1.4
15		2C1	0.41	0.46	0.46	1.46	26	19.7	18.3	16.4	16.0	69.4	69.9	168	14.0	1.4
16		4C2	0.26	0.28	0.31	1.44	23	18.5	17.4	15.9	15.5	69.4	71.5	167	13.3	1.5
17		14C3	0.20	0.35	0.38	1.52	24	18.6	17.7	16.6	15.8	73.4	74.1	168	13.2	1.54
18		15C4	0.23	0.37	0.40	1.41	24	18.7	17.8	16.1	15.2	71.3	71.8	168	13.1	1.4
19		25C5	0.39	0.45	0.50	1.24	28	18.8	18.2	15.0	14.4	69.3	70.8	169	13.6	1.4
20		23C6	0.25	0.32	0.38	1.33	24	18.8	16.8	15.7	13.8	69.2	65.5	169	13.4	1.3
21		5D1	0.09	0.23	0.24	1.77	36	28.0	26.7	22.0	21.2	55.2	55.1	176	18.5	2.1
22		6D2	0.00	0.00	0.00	0.00	0.0	0.0	18.7	0.0	15.0	0.0	68.4	168	12.7	1.8
23		1D3	0.38	0.40	0.42	1.32	23	18.8	17.6	15.3	14.8	69.4	70.0	166	14.9	1.9
24		9D4	0.37	0.40	0.41	1.29	22	19.3	18.7	14.9	15.2	66.6	72.4	166	13.9	1.4
25		7D5	0.29	0.42	0.44	1.12	23	21.0	20.2	15.0	14.7	68.1	69.7	167	15.0	1.3
26		8D6	0.57	0.64	0.67	1.03	24	20.2	21.2	13.4	14.1	65.4	68.9	172	15.2	1.4
27		18E1	0.25	0.30	0.33	1.52	24	17.3	17.0	15.4	15.2	68.1	72.0	169	13.1	1.3
28		17E2	0.34	0.42	0.46	1.46	23	18.0	17.8	15.3	15.4	67.6	72.0	168	13.8	1.4
29		13E3	0.32	0.38	0.42	1.46	22	18.2	17.2	16.5	15.9	71.5	73.1	169	13.6	1.4
30		12E4	0.39	0.47	0.47	1.47	22	18.1	17.4	16.3	16.1	71.4	74.3	169	13.1	1.6
31		11E5	0.46	0.51	0.53	1.31	22	18.1	18.1	15.3	16.3	67.7	74.8	171	13.6	1.2
32		10E6	0.68	0.74	0.75	2.00	35	25.2	26.1	22.1	23.6	107.3	115.7	245	18.2	2
33		53AA1	0.32	0.31	0.32	1.52	24	18.7	18.3	15.7	15.7	68.3	69.2	170	13.0	2.2
34		55AA2	0.29	0.27	0.29	1.49	25	17.9	17.8	15.2	15.2	66.1	67.6	174	11.7	1.7
35		56AA3	0.35	0.34	0.33	1.49	24	18.4	18.3	15.5	15.7	68.7	70.9	169	12.7	2.0
36		57AA4	0.48	0.42	0.41	1.59	25	19.2	19.6	16.4	17.2	72.9	77.9	171	16.2	1.9
37		58AA5	1.0	0.92	1.0	2.44	44	34.8	35.2	25.5	27.0	111.2	117.9	283	24.0	3.3
38		59AA6	0.56	0.49	0.57	1.57	24	17.8	17.6	15.6	15.7	67.3	67.5	173	13.0	2.1
39		75BB1	0.22	0.22	0.26	1.29	20	1.94	19.3	14.1	14.3	64.3	65.8	167	12.6	1.8
40		74BB2	0.30	0.28	0.32	1.49	23	19.9	19.8	14.7	15.0	68.8	70.7	170	13.6	1.8
41		77BB3	0.30	0.30	0.33	1.33	23	20.7	20.1	14.9	14.8	64.7	65.5	168	13.4	1.8
42		80BB4	0.35	0.42	0.47	1.07	22	22.8	22.4	13.7	13.5	61.4	62.2	172	14.1	1.9
43		79BB5	0.12	0.23	0.26	1.27	20	18.7	18.8	14.6	14.6	65.4	67.3	173	12.6	1.7
44		61BB6	0.22	0.21	0.0	0.0	0.0	18.1	18.1	13.7	13.9	61.6	64.2	165	11.4	1.7
45		78CC1	0.23	0.28	0.31	1.37	22	19.4	19.4	15.1	15.2	67.1	69.1	176	13.3	1.7

Ions and avg (ACS)

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
2		Sample	Ca			B	Li	Mg		K		Na		Cl	SO_4	Br
46		76CC2	0.24	0.29	0.33	1.41	22	18.2	18.5	15.3	15.7	69.0	72.4	168	13.6	1.8
47		74CC3	0.33	0.29	0.30	1.33	22	18.3	18.1	15.6	15.8	66.3	68.9	168	13.0	1.8
48		68CC4	0.33	0.32	0.37	1.46	23	17.9	17.5	14.9	14.6	67.3	67.3	176	13.7	1.7
49		62CC5	0.33	0.31	0.25	1.31	21	18.9	18.4	15.4	15.1	66.5	67.4	184	13.4	1.8
50		63CC6	0.46	0.55	0.60	1.46	23	17.3	18.0	15.3	15.8	68.7	73.0	170	14.7	1.8
51		69DD2	0.23	0.27	0.29	1.45	22	18.8	17.7	15.1	14.4	66.0	65.2	167	13.1	1.9
52		72DD3	0.57	0.54	0.58	1.11	23	20.4	20.5	14.2	14.3	64.3	66.8	171	14.2	1.9
53		65DD4	0.21	0.28	0.31	1.46	23	19.5	20.0	15.1	15.6	65.0	67.8	174	13.0	2.2
54		64DD5	0.36	0.47	0.51	1.05	21	20.6	20.5	12.9	12.9	60.0	61.7	172	14.2	1.7
55		66DD6	0.56	0.62	0.67	1.24	23	18.5	18.9	14.8	15.1	68.3	70.7	171	14.9	2.1
56		49A1	0.43	0.52	0.59	1.44	27	22.5	22.7	14.6	14.6	63.0	62.3	175	14.4	1.8
57		50A2	0.43	0.48	0.54	1.31	29	21.6	22.1	13.3	13.8	60.3	61.9	171	14.1	1.7
58		51A3	0.27	0.42	0.43	1.42	25	21.3	21.8	13.9	14.0	61.8	61.7	170	13.2	1.6
59		52A4	0.19	0.33	0.33	1.44	30	21.3	22.0	13.8	14.1	61.8	61.7	173	12.9	1.8
60		47A5	0.21	0.33	0.32	1.50	26	21.1	21.6	13.8	14.0	62.4	63.0	174	12.5	1.8
61		45A6	0.45	0.54	0.61	1.44	26	23.2	23.3	14.7	14.7	62.5	61.7	177	14.9	1.8
62		37B1	0.05	0.20	0.22	1.82	29	34.1	32.1	17.7	16.2	44.3	44.6	177	17.8	2.5
63		38B2	0.53	0.76	0.80	1.35	27	24.3	25.1	15.2	14.9	63.8	64.4	184	15.9	1.9
64		41B3	0.39	0.66	0.65	1.43	34	23.3	23.9	15.3	14.9	61.6	61.6	178	14.0	1.9
65		43B4	0.35	0.53	0.52	1.79	36	37.0	35.3	19.1	17.8	46.8	48.5	191	20.8	2.8
66		42B5	0.51	0.64	0.72	1.36	28	24.4	24.1	15.7	15.4	62.2	61.5	178	15.2	1.9
67		46B6	0.13	0.25	0.27	1.36	27	23.2	23.2	14.3	14.2	59.6	59.3	172	13.0	1.9
68		31C1	0.14	0.31	0.28	1.27	26	22.0	22.4	13.6	13.7	60.1	60.3	169	13.5	1.7
69		32C2	0.10	0.27	0.26	1.21	21	21.8	22.0	13.3	13.3	59.8	59.8	168	14.4	1.7
70		33C3	0.11	0.26	0.26	1.26	26	21.9	21.5	13.5	13.5	62.2	62.1	171	14.6	1.7
71		34C4	0.15	0.27	0.28	1.28	24	22.2	22.1	13.7	13.8	60.2	59.9	169	14.2	1.7
72		36C5	0.36	0.53	0.58	1.27	23	22.5	22.1	13.8	13.4	62.7	60.8	172	13.4	1.8
73		40C6	0.09	0.26	0.25	1.30	31	22.3	22.4	13.8	13.6	60.9	59.8	170	13.1	1.8
74		44D1	0.21	0.32	0.33	1.46	23	20.6	20.8	14.0	14.1	63.0	63.5	170	13.2	1.6
75		48D2	0.43	0.54	0.55	1.33	28	20.9	21.0	14.0	14.1	64.5	64.2	171	14.5	1.6
76		35D3	0.35	0.55	0.54	1.41	22	20.9	20.9	14.4	14.2	63.6	63.3	171	14.2	1.6
77		39D4	0.25	0.55	0.51	1.34	27	21.2	21.8	14.8	14.7	63.1	63.1	171	14.3	1.7
78		60D5	0.39	0.57	0.51	1.81	31	22.5	23.0	15.9	15.9	60.8	62.2	176	14.2	1.9
79		54D6	0.42	0.60	0.57	1.42	25	20.5	20.9	14.0	14.1	63.7	64.0	172	13.8	1.6
80				**Ca raw**	**Ca w/ I.S.**	**B**	**Li**	**Mg raw**	**Mg w/I.S.**	**K raw**	**K w/ I.S.**	**Na raw**	**Na w.I.S.**	**Cl**	**SO4**	**Br**
81		**AVG**	ppt	0.47	0.46	1.42	25	20.5	20.6	15.2	15.2	66.0	67.6	173	14.2	1.8
82			Std	0.35	0.21	0.21	4	4.5	4.2	2.3	2.3	10.4	11.5	16	2.0	0.5
83																
84			ppm	Raw	Corrected											

Ions and avg (ACS) (continued)

	A	B	C	D	E	F	G	H
1		Internal Stand data was used			specific gravity	1.2kg/l		
2								
3				molal	molar		mixed	
4	element	ppt (g/Kg)	ppm (mg/Kg)	moles/Kg	moles/L	mM	molar	ratio check
5	Ca	0.46		0.011	0.014	14	0.014	0.985221675
6	B	1.42		0.131	0.157	157	0.155	0.985221675
7	Li	0.025	25.284	0.0036	0.0044	4.4	0.0043	0.985221675
8	Mg	20.6		0.847	1.02		1.00	0.985221675
9	K	15.2		0.388	0.465	465	0.458	0.985221675
10	Na	67.6		2.94	3.53		3.48	0.985221675
11	Cl	173		4.89	5.87		5.51	0.939182254
12	SO4	14.2		0.148	0.177	177	0.175	0.985221675
13	Br	1.8		0.022	0.027	27	0.026	0.985221675
14								
15	Salt calculations							
16								
17		1) Keep track of Na balance, for 1 Kg solution						
18								
19			moles/Kg	Salt	moles Na remaining			
20		SO4	0.148	Na2SO4	2.647			
21		Br	0.022	NaBr	2.625			
22		B	0.0327	l2B4O7 10H	2.559			
23								
24								
25		2) Keep track of Cl balance, for 1 Kg solution						
26								
27			Moles/Kg	Salt	moles Cl remaining			
28		Ca	0.0115	CaCl2 2H2C	4.869			
29		Li	0.0036	LiCl	4.865			
30		Mg	0.8471	MgCl2 6H2C	3.171			
31		K	0.3876	KCl	2.783			
32		Na	2.559	NaCl	0.2242	#		
33								
34	#	To achieve an exact charge balance, chloride will be the adjustable paramater						
35		% less Cl						
36		4.584						

Molarity & Salt wt calcs (ACS)

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	A	B	C	D	E	F	G	H
37								
38								
39		Weight of Salts for 1 Kg solution			(analyzed)	(mixed)		
40						*		
41		Salt	moles	FW (g/mol)	grams (salt)	grams (salt)	revised moles	
42		Na2SO4	0.1478	142.04	20.99	20.68	0.145614373	
43		NaBr	0.0222	102.89	2.282	2.248	0.021849332	
44		Na2B4O7 10H2O	0.03275	381.38	12.49	12.30	0.032262272	
45		CaCl2 2H2O	0.0115	147.012	1.684	1.659	0.011287504	
46		LiCl	0.0036	42.391	0.1544	0.1521	0.003588839	
47		MgCl2 6H2O	0.8471	203.306	172.2	169.7	0.834601767	
48		KCl	0.3876	74.55	28.90	28.47	0.38188916	
49		NaCl	2.559	58.44	149.6	147.3	2.521355513	
50		**Total**			**388.282**			
51						(mixed)		
52		DI water			611.718	617.455738		
53					plus 15 g			
54					626.718			
55								
56	*	additional 15g of water is added to dissolve all the salts.						
57		all salts and water must be mulitplied by			0.985221675	to make 1 kg brine.		

molarity & salt wt calcs (ACS)

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Brine comparison (ACS)

	A	B	C	D	E	F	G	H	I	J
1		GWB recipe from Zhang et al. (1999) "Kinetics and Mechanisms of Formation of Magnesite from Hydromagnesite in Brine".								
2										
3										
4		Salt	g/L	FW (g/mol)						
5		Na_2SO_4	25.23	142.04						
6		NaBr	2.74	102.89						
7		$Na_2B_4O_7\ 10H_2O$	15.06	381.38		moles/L				
8		NaCl	179.61	58.44	Na or Cl	3.073				
9		KCl	34.84	74.55						
10		$MgCl_2\ 6H_2O$	207.05	203.306						
11		LiCl	0.19	42.391						
12		$CaCl_2\ 2H_2O$	2.03	147.012						
13										
14										
15			Molar	Zhang	JK (Oct memo)	JK (May memo)	ACS recreation			
16		Ions	moles/L							
17		B	0.1580	158	158	158	157			
18		Ca	0.0138	13.8	13.8	14	13.7			
19		K	0.4673	467	466	467	465			
20		Mg	1.02		1.02	1.02	1.02			
21		Na	3.77		3.53	3.53	3.53			
22		Br	0.0266	26.6	26.5	26.6	26.6			
23		Cl	5.61		5.86	5.86	5.87			
24		SO_4	0.1776	178	177	177	177			
25		Li	0.0045	4.48			4.37			