**Supplementary Information**

1. *Elemental analysis*

The trace impurities in LiCl-KCl samples were analyzed using ICP-OES analysis. The analysis for the main salt impurities Al, Ca, Fe, Mg, Mn and Na are reported in the Table below, followed by the detailed procedure, digestion methods and sample analyses.

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| --- | --- | --- | --- | --- | --- | --- | --- |
| **ICP-OES Results** |  | **OES** | **OES** | **OES** | **OES** | **OES** | **OES** |
| **sample** |  | **µg Al/ mL** | **µg Ca/ mL** | **µg Fe/ mL** | **µg Mg/ mL** | **µg Mn/ mL** | **µg Na/ mL** |
| Detection Limit |  | 0.007 | 0.016 | 0.008 | 0.009 | 0.008 | 0.010 |
|  |  |  |  |  |  |  |  |
| mean % error |  | 4.8 ± 1.6 | -2.9 ± 2.8 | -1.7 ± 1.5 | 0.6 ± 2.2 | -0.3 ± 1.5 | 4.3 ± 1.6 |
|  |  |  |  |  |  |  |  |
| RG-6 **Spike** |  | 2.113 | 1.812 | 1.879 | 2.169 | 2.041 | 3.121 |
|  | % Recovery | 102.4 | 86.6 | 91.2 | 105.2 | 99.1 | 143.9 |
|  |  |  |  |  |  |  |  |
| **Sample** | **mol%LiCl** | **Wt% Al** | **Wt% Ca** | **Wt% Fe** | **Wt% Mg** | **Wt% Mn** | **Wt% Na** |
| S1 | 93 | 0.0011 | 0.0025 | < 0.0005 | < 0.0005 | < 0.0005 | 0.0051 |
| S2 | 80 | 0.0008 | < 0.0012 | 0.0008 | < 0.0007 | < 0.0006 | 0.0056 |
| S3 | 40 | 0.0007 | 0.0021 | < 0.0006 | 0.0077 | < 0.0005 | 0.0070 |
| S4 | 20 | < 0.0005 | < 0.0010 | < 0.0006 | < 0.0006 | < 0.0005 | 0.0060 |
| S5 | 10 | 0.0005 | < 0.0010 | < 0.0006 | < 0.0006 | < 0.0005 | 0.0110 |
| S6 | 58.2 | 0.0012 | 0.0040 | < 0.0006 | < 0.0006 | < 0.0006 | 0.0100 |

Labware and Reagents:

All labware used for the digestion procedure of the solid samples was first analytically washed, rinsed with Nanopure H2O, and acid leached for 24 hours in a 25% HNO3 bath, and rinsed again using Nanopure H2O.

All acids used for the dissolution of the solid samples were the ultrapure Optima grade from Fisher. The Nanopure H2O for the procedure was from the building purification system and was passed through a Lab cleansing unit from Elga to provide analytically pure H2O 18.2 Mega Ohms.

Lab Procedure:

0.3g to 0.5g of sample was weighed out into a tarred Teflon 25 mL beaker. The side of the beaker was rinsed with Nanopure H2O – to collect all the sample in the bottom of the vessel (~0.5 mL). 2.5 mLs of Nitric acid was added to the beaker with the sample. The beaker was placed on the hotplate, covered with a Telfon watchglass and heated. Once the sample was dissolved, the beaker was removed from the hotplate and sample was allowed to cool down. The sample was analytically transferred to a 25 mL poly volumetric flask and diluted to volume with Nanopure H2O. The sample was transferred to a 50 mL poly tube which has been labeled with the sample ID. All samples are filtered through a 0.45 micron PTFE filter prior to dilution for ICP analysis. A Method Blank was prepared by following the same steps as outlined above but substituting 1 mL of H2O for the solid sample.

Procedure Note: All the samples were easily and completely digested using minimum heat in approximately two hours.

Method Blank Sample Note: No sample contamination for the any of the elements was found for the reagents used or the digestion procedure.

# ICP-OES Introduction/Methods:

An inductively coupled plasma optical emission spectrophotometer (ICP-OES) iCAP Series 6000 from Thermo Scientific was used to measure aluminum, calcium, iron, lithium, magnesium, manganese, potassium, and sodium.

Quality Control\Quality Assurance (QA\QC):

A sample spike or laboratory control standard (LCS) is also analyzed. The LCS analyses are performed to assure accuracy and precision of the analysis. A continuing calibration verification standard (CCV) and a continuing calibration blank (CCB) are analyzed throughout the analysis to monitor instrument performance. The detection limit of instrument for each element is determined by multiplying three times the standard deviation (n>3) of the all the CCB standards analyzed.

Internal Standard: An internal standard of scandium for ICP-OES analysis is introduced into each sample and all standards using online injection at 2 parts per million (ppm) in order to correct for any matrix problems.

## Standards Preparations:

All standards are prepared from commercial stock solutions. Concentrated nitric (HNO3) acid was added to produce a 2% HNO3 acid matrix, so as to match the matrix of the samples. All commercial stock solutions used to prepare calibrations standards and CCV standards are obtained from vendors that are NIST traceable. For QA\QC purposes, the commercial stock solutions for the calibration standards and the CCV standards are from different vendors who are independent of each other. Commercial stock solutions used for CCV standards are a multi-element solution.

ICP-OES: Calibration standards used to standardize the instrument are prepared from commercial stock solutions of 1000 ppm. The range of the calibration for each element for the ICP-OES was from 0 ppm to 40 ppm, (0 ppm, 2 ppm, 5 ppm, 10 ppm, 20 ppm, and 40 ppm). A CCV standard was prepared from a commercial multi-element solution of 100 ppm acquired from a 2nd independent vendor.

## Sample Analyses:

The ICP-OES was operated and calibrated in accordance with the manufacturer’s instructions. The R Square value of the calibration curve must be < 0.997. Failure to meet this condition results in the instrument being recalibrated. The percent error of the CCV standards is monitored during the analysis and if it is found to be greater than ±10%, the instrument is normalized. All sample analyses are bracketed by CCV and CCB standards. The ICP-OES wavelengths used for each element are inspected for possible interferences from other elements and the sample matrix. A Method Blank sample (described in the digestion procedure) was analyzed along with the digested samples to identify if any contamination is being picked up during the digestion procedure or from the reagents used to dissolve the samples. If any contamination was identified for an element, the reported results are adjusted for the contamination found.

1. *Density measurements*

Density equation

Uncertainty of density value

|  |  |
| --- | --- |
| Variable | Assigned Error |
| (mass of bobber + wire in argon) | 0.001 g |
| (weight of bobber + wire submerged in salts) | 0.001 g |
| (diameter of wire) | 1% of D |
| (surface tension of salt) | 0.76% of |
| (volume of bobber at T=20°C) | Standard deviation of average from water and ethanol measurements |
| (linear coefficient of thermal expansion for nickel) | 0.5% of C |
| (temperature) | 0.003\*T+1 (K) |

Data

Bobber volume measurement

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Ni** | T (°C) | T (°C) |
|  | **14.7602 g** | 22.1 | 21.7 |
|  | grams | grams | grams |
|  | Air | Water | Ethanol |
| **Weight (g)** | 14.8038 | 13.1430 | 13.4936 |
| 14.8038 | 13.1426 | 13.4940 |
| 14.8038 | 13.1430 | 13.4942 |
| **14.8038** | **13.1429** | **13.4939** |
| Volume (cm3) | 1.6652 | 1.6647 | 1.6628 |
| 1.6651 | 1.6646 | 1.6627 |
|  |  |  |  |
|  |  | Average | Error |
|  | Volume (cm3) | **1.6636** | **0.0013** |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **0 mol% KCl (100 mol% LiCl)** |  |  |  |  |
| T (°C) | T (K) | ρ salt (g cm-3) | error\_ρ salt (g cm-3) | error\_T (K) |
| 619 | 892 | 1.5072 | 0.0105 | 2.86 |
| 650 | 923 | 1.4907 | 0.0103 | 2.95 |
| 700 | 973 | 1.4687 | 0.0101 | 3.10 |
| 748 | 1021 | 1.4480 | 0.0098 | 3.24 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **7 mol% KCl (93 mol% LiCl)** | |  |  |  |
| T (°C) | T (K) | ρ salt (g cm-3) | error\_ρ salt (g cm-3) | error\_T (K) |
| 744 | 1017 | 1.4522 | 0.0098 | 3.23 |
| 699 | 972 | 1.4725 | 0.0101 | 3.10 |
| 651 | 924 | 1.4952 | 0.0104 | 2.95 |
| 622 | 895 | 1.5110 | 0.0105 | 2.87 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **20 mol% KCl (80 mol% LiCl)** |  |  |  |  |
| T (°C) | T (K) | ρ salt (g cm-3) | error\_ρ salt (g cm-3) | error\_T (K) |
| 702 | 975 | 1.4881 | 0.0102 | 3.11 |
| 655 | 928 | 1.5109 | 0.0105 | 2.97 |
| 606 | 879 | 1.5352 | 0.0108 | 2.82 |
| 555 | 828 | 1.5606 | 0.0111 | 2.67 |
| 594 | 867 | 1.5419 | 0.0109 | 2.78 |
| 646 | 919 | 1.5154 | 0.0105 | 2.94 |
| 701 | 974 | 1.4887 | 0.0102 | 3.10 |
| 748 | 1021 | 1.4665 | 0.0099 | 3.24 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **60 mol% KCl (40 mol% LiCl)** |  |  |  |  |
| T (°C) | T (K) | ρ salt (g cm-3) | error\_ρ salt (g cm-3) | error\_T (K) |
| 652 | 925 | 1.5607 | 0.0108 | 2.96 |
| 604 | 877 | 1.5873 | 0.0111 | 2.81 |
| 699 | 972 | 1.5328 | 0.0105 | 3.10 |
| 649 | 922 | 1.5590 | 0.0108 | 2.95 |
| 700 | 973 | 1.5354 | 0.0105 | 3.10 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **41.8 mol%KCl (58.2 mol% LiCl)** |  |  |  |  |
| T (°C) | T (K) | ρ salt (g cm-3) | error\_ρ salt (g cm-3) | error\_T (K) |
| 791 | 1064 | 1.4691 | 0.0099 | 3.37 |
| 702 | 975 | 1.5093 | 0.0103 | 3.11 |
| 650 | 923 | 1.5384 | 0.0107 | 2.95 |
| 600 | 873 | 1.5644 | 0.0110 | 2.80 |
| 450 | 723 | 1.6500 | 0.0123 | 2.35 |
| 595 | 868 | 1.5583 | 0.0110 | 2.79 |
| 548 | 821 | 1.5857 | 0.0113 | 2.64 |
| 500 | 773 | 1.6078 | 0.0117 | 2.50 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **80 mol% KCl (20 mol% LiCl)** |  | | |  |  |
| T (°C) | | T (K) | ρ salt (g cm-3) | error\_ρ salt (g cm-3) | error\_T (K) |
| 702 | | 975 | 1.5588 | 0.0110 | 3.11 |
| 725 | | 998 | 1.5452 | 0.0109 | 3.18 |
| 748 | | 1021 | 1.5299 | 0.0107 | 3.24 |
| 774 | | 1047 | 1.5144 | 0.0106 | 3.32 |
| 797 | | 1070 | 1.5009 | 0.0104 | 3.39 |
| 820 | | 1093 | 1.4839 | 0.0103 | 3.46 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **90 mol% KCl (10 mol% LiCl)** |  |  |  |  |
| T (°C) | T (K) | ρ salt (g cm-3) | error\_ρ salt (g cm-3) | error\_T (K) |
| 766 | 1039 | 1.5230 | 0.0103 | 3.30 |
| 788 | 1061 | 1.5105 | 0.0102 | 3.36 |
| 806 | 1079 | 1.4990 | 0.0100 | 3.42 |
| 828 | 1101 | 1.4864 | 0.0099 | 3.48 |
| 813 | 1086 | 1.4954 | 0.0100 | 3.44 |
| 793 | 1066 | 1.5064 | 0.0101 | 3.38 |
| 772 | 1045 | 1.5190 | 0.0102 | 3.32 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **100 mol% KCl (0 mol% LiCl)** |  |  |  |  |
| T (°C) | T (K) | ρ salt (g cm-3) | error\_ρ salt (g cm-3) | error\_T (K) |
| 799 | 1072 | 1.5105 | 0.0105 | 3.40 |
| 819 | 1092 | 1.4974 | 0.0104 | 3.46 |
| 838 | 1111 | 1.4838 | 0.0102 | 3.51 |
| 857 | 1130 | 1.4716 | 0.0101 | 3.57 |