

CRWMS/M&O

**Calculation Cover Sheet**

Complete only applicable items.

1. QA: L

Page: 1

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MOL.19990215.0397

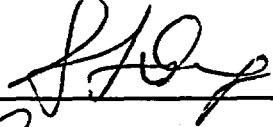
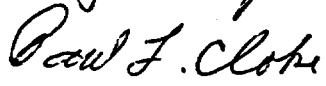
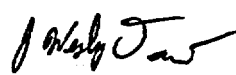
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DOE SRS HLW Glass Chemical Composition

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5. Total Attachments  
3

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| 00               |                   | Initial Issue               |

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**TABLES**

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## **1. PURPOSE**

The purpose of this engineering calculation is to provide the chemical composition for the Department of Energy (DOE) Savannah River Site (SRS) High-Level Waste (HLW) glass. Since the glass is to be co-disposed with other DOE spent nuclear fuels (SNFs) in the Monitored Geologic Repository (MGR), its chemical composition is needed for the design of the co-disposal canisters and waste packages in term of criticality and degradation.

## **2. METHOD**

The chemical composition is expressed in weight percent (wt%). Reference 1 provides the radioisotope contents and chemical composition in compound form (including oxide) for the SRS HLW glass (Tables 6.14 and 6.18). The wt% for the isotopes are calculated directly by knowing their masses in the glass (given in Table 6.14 of Ref. 1) and the total glass weight in the canister (given in Table 6.4 of Ref. 1). The wt% of each element in the compound including the oxide is calculated by the steps listed below. Attachment II provides the formulas involved in the wt% calculations.

- (1) Determine the fraction of each element in the compound using the atomic weight.
- (2) Determine the mass of the compound in the glass.
- (3) Multiply (1) and (2) above to obtain the wt% for each element in the compound including the oxygen.
- (4) Sum the wt% of an element in each compound in which it occurs to obtain the total wt% of each element in the glass.
- (5) Add up the wt% of each element in (4) above to obtain a total, ignoring any unidentified components.
- (6) Normalized the results in (5) above to 100 %.

## **3. ASSUMPTIONS**

- 3.1 For this calculation, only those isotopes with very long half-life and large amount in the glass are considered. The basis for this assumption is that any isotope with a half life of less than 400 years would have already decayed away as compared to the assumed life time of the intact waste package (about 3000 years, CDA Key 074). Also any isotope with an amount of less than 0.0001 wt% would have no effect on criticality. As a result, only U-234, -235, -236, -238; Pu-238, -239, -240, -241, -242 and Cs-133, -135 and -137 are retained for this calculation. This assumption is used in Section 5.1.
- 3.2 Stable Cs is assumed to be Cs-133. Cs-137 is assumed to have decayed to Ba-137 (Ref. 2). This assumption is used in Section 5.1.

- 3.3 It was very difficult to define the "0.58% of Other" group in Table 6.18 of Ref. 1. It is assumed this amount was a result of uncertainty in the chemical analysis and was ignored in this calculation. The weight percent for all other elements was re-normalized to 100%. This assumption is used in Section 5.1.
- 3.4 The dominant (most abundant) alkali or alkaline earth is Na. Consequently, it is assumed that the zeolite can be approximated as analcime, which, because of the high temperature of the pour, is assumed to be anhydrous, i.e.  $\text{NaAlSi}_2\text{O}_6$ . The chemical compound of zeolite is therefore assumed to take the form of  $\text{NaAlSi}_2\text{O}_6$  (Ref. 3). This assumption is used in Section 5.1.

#### **4. USE OF COMPUTER SOFTWARE**

##### **4.1 SOFTWARE APPROVED FOR QA WORK**

No computer software is used for this calculation.

##### **4.2 SOFTWARE ROUTINES**

Microsoft Excel 97, loaded on a 200MHz Pentium PC. Hand calculations of the chemical composition for the SRS HLW glass were performed electronically with this spreadsheet software package. Hardcopies of the spreadsheets containing all inputs and outputs are included in Attachments I, II and III. Calculations and/or data manipulations performed in the spreadsheets are described in Section 5 and may also be examined electronically.

#### **5. CALCULATION**

The chemical composition calculations were performed in an Excel spreadsheet. Attachments I, II and III are the printouts of the Excel spreadsheet. Attachment I lists the results of this calculation. Attachments II and III contain the details of the calculations including the formulas used in determining the mole fractions, wt%, etc.

##### **5.1 INPUT PARAMETERS**

The input parameters used for this calculation are listed below. Existing data were used in the development of the input parameters presented in this section. Therefore, the use of any data from this calculation for input into documents supporting procurement, fabrication, or construction is required to be identified and tracked as TBV in accordance with appropriate procedures.

- (A) Radioisotope content in the SRS HLW glass (Ref. 1, Table 6.14)
- (B) Chemical composition of SRS HLW glass which contains the chemical compound including the oxides (Ref. 1, Table 6.18)
- (C) Glass total weight (Ref. 1, Table 6.4)
- (D) Atomic weight for each element (Refs. 2 and 4)

Note that two references were used in determining the atomic weight for the different element in the calculations. Reference 2 was used for determining the atomic weight for the natural elements and reference 4 was used for determining the atomic weight for the isotopes.

## 6. RESULTS

Complete results from this calculation are included in Attachments I, II and III. A summary of the chemical composition for the SRS HLW glass is shown in Table 1 below. Existing data were used in the development of the results presented in this section. Therefore, the use of any data from this calculation for input into documents supporting procurement, fabrication, or construction is required to be identified and tracked as TBV in accordance with appropriate procedures.

Table 1 SRS HLW Glass Chemical Composition

| Element           | Weight Percent | Element           | Weight Percent |
|-------------------|----------------|-------------------|----------------|
| <sup>6</sup> Li   | 9.5955E-02     | <sup>7</sup> Li   | 1.3804E+00     |
| <sup>10</sup> B   | 5.9176E-01     | <sup>11</sup> B   | 2.6189E+00     |
| O                 | 4.4770E+01     | F                 | 3.1852E-02     |
| Na                | 8.6284E+00     | Mg                | 8.2475E-01     |
| Al                | 2.3318E+00     | Si                | 2.1888E+01     |
| S                 | 1.2945E-01     | K                 | 2.9887E+00     |
| Ca                | 6.6188E-01     | Ti                | 5.9676E-01     |
| Mn                | 1.5577E+00     | Fe                | 7.3907E+00     |
| Ni                | 7.3490E-01     | P                 | 1.4059E-02     |
| Cr                | 8.2567E-02     | Cu                | 1.5264E-01     |
| Ag                | 5.0282E-02     | Ba-137            | 1.1267E-01     |
| Pb                | 6.0961E-02     | Cl                | 1.1591E-01     |
| <sup>232</sup> Th | 1.8559E-01     | <sup>133</sup> Cs | 4.0948E-02     |
| <sup>135</sup> Cs | 5.1615E-03     | <sup>234</sup> U  | 3.2794E-04     |
| <sup>236</sup> U  | 1.0415E-03     | Zn                | 6.4636E-02     |
| <sup>235</sup> U  | 4.3514E-03     | <sup>238</sup> U  | 1.8666E+00     |
| <sup>238</sup> Pu | 5.1819E-03     | <sup>239</sup> Pu | 1.2412E-02     |
| <sup>240</sup> Pu | 2.2773E-03     | <sup>241</sup> Pu | 9.6857E-04     |
| <sup>242</sup> Pu | 1.9168E-04     |                   |                |

## 7. REFERENCES

1. Stout, R.B. and Leider, H.R. 1991. *Preliminary Waste Form Characteristics Report*. Version 1.0. Livermore, California: UC/LLNL. MOL.19940726.0118.
2. Walker, F.W. and Parrington, J.R. 1989. *Nuclides and Isotopes 14<sup>th</sup> Edition*. San Jose, California: GE Nuclear Energy. 201637.
3. Roberts, W.L.; Rapp, G.R. Jr.; and Weber, J. 1974. *Encyclopedia of Minerals, Zeolite Group*, pages 20 and 685. New York, New York: Van Nostrand Reinhold Company. 241748.
4. Audi, G. and Wapstra, A.H. 1995. *The 1995 Update to the Atomic Mass Evaluation*. Nuclear Physics A595, Vol. A595, no.1, pages 1-65. North-Holland, The Netherlands: Elsevier N.H. 242718.



**8. ATTACHMENTS**

The first attachment to this document is a printout of the MS Excel spreadsheet showing the results of the SRS HLW glass chemical composition calculation. The second attachment is a printout of the Excel spreadsheet showing the formulas used to calculate the glass chemical composition. The third attachment is a printout of the Excel spreadsheet showing the formulas used to calculate the summary of the glass chemical composition.

**Table 2 List of Attachments**

| <b>Number</b> | <b>Description</b>   | <b>Number of Pages</b> |
|---------------|--|------------------------|
| I             | SRS HLW Glass Chemical Composition Calculation Results (Printout)          | 7                      |
| II            | SRS HLW Glass Chemical Composition Calculation Formulas (Printout)         | 4                      |
| III           | SRS HLW Glass Chemical Composition Calculation Summary Formulas (Printout) | 2                      |

Attachment I SRS HLW Glass Chemical Composition Calculation Results

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|    | A  | B         | C                | D           | E             | F               | G               | H | I |
|----|--|-----------|------------------|-------------|---------------|-----------------|-----------------|---|---|
| 1  | Element/Compound                             | Atm. Wt.  | Mass in Canister | Wt. %       | Element Moles | Moles of Oxygen | Wt. % of Oxygen |   |   |
| 2  | Group  |           | (gram)           |             |               |                 |                 |   |   |
| 3  | Oxygen                                       | 15.9994   |                  |             |               |                 |                 |   |   |
| 4  |  |           |                  |             |               |                 |                 |   |   |
| 5  | U-234  | 234.0409  | 5.485            | 0.0003281   | 1.39335E-06   | 3.71559E-06     | 5.94472E-05     |   |   |
| 6  | U-235  | 235.04392 | 72.78            | 0.004326992 | 1.84093E-05   | 4.90914E-05     | 0.000785434     |   |   |
| 7  | U-236  | 236.04556 | 17.42            | 0.001035672 | 4.38759E-06   | 1.17002E-05     | 0.000187197     |   |   |
| 8  | U-238  | 238.05078 | 3.12E+04         | 1.856123662 | 0.007797175   | 0.020792467     | 0.332667004     |   |   |
| 9  | Total Unstable U Mass                        |           | 3.13E+04         | 1.861812428 |               |                 |                 |   |   |
| 10 | Total Oxygen                                 |           |                  |             |               |                 | 0.333699082     |   |   |
| 11 | Total U <sub>3</sub> O <sub>8</sub> (note a) |           |                  | 2.2         |               |                 |                 |   |   |
| 12 |  |           |                  |             |               |                 |                 |   |   |
| 13 | Pu-238                                       | 238.04955 | 86.67            | 0.005152794 | 2.16459E-05   | 4.32918E-05     | 0.000692642     |   |   |
| 14 | Pu-239                                       | 239.05215 | 207.6            | 0.012342449 | 5.16308E-05   | 0.000103262     | 0.001652123     |   |   |
| 15 | Pu-240                                       | 240.05381 | 38.09            | 0.002264568 | 9.43358E-06   | 1.88672E-05     | 0.000301863     |   |   |
| 16 | Pu-241                                       | 241.05684 | 16.2             | 0.000963139 | 3.99549E-06   | 7.99097E-06     | 0.000127851     |   |   |
| 17 | Pu-242                                       | 242.05873 | 3.206            | 0.000190606 | 7.87439E-07   | 1.57488E-06     | 2.51971E-05     |   |   |
| 18 | Total Unstable Pu Mass                       |           | 3.52E+02         | 0.020913555 |               |                 |                 |   |   |
| 19 | Total Oxygen                                 |           |                  |             |               |                 | 0.002799677     |   |   |
| 20 |  |           |                  |             |               |                 |                 |   |   |
| 21 | Cs-135                                       | 134.90597 | 86.33            | 0.00513258  | 3.80456E-05   | 1.90228E-05     | 0.000304353     |   |   |
| 22 | Cs-137                                       | 136.9071  | 498.9            | 0.029661118 | 0.000216651   | 0.000108328     | 0.001733146     |   |   |
| 23 | Unstable Cs <sub>2</sub> O-Total             |           |                  | 0.036831198 |               |                 |                 |   |   |
| 24 | Total Cs <sub>2</sub> O (note a)             |           |                  | 0.08        |               |                 |                 |   |   |
| 25 | Stable Oxide                                 |           |                  | 0.043168802 |               |                 |                 |   |   |
| 26 | Stable Cs Oxide Mass                         |           | 728.0992524      |             |               |                 |                 |   |   |
| 27 | Total Unstable Mass                          |           | 585.23           |             |               |                 |                 |   |   |
| 28 | Cs-133                                       | 132.90544 |                  | 0.040717951 | 0.000306368   | 0.000153184     | 0.002450851     |   |   |
| 29 |  |           |                  |             |               |                 |                 |   |   |
| 30 | Ba-137                                       |           |                  | 0.029661118 |               |                 |                 |   |   |
| 31 | (same as Cs137)                              |           |                  |             |               |                 |                 |   |   |
| 32 |  |           |                  |             |               |                 |                 |   |   |

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|    | A   | B         | C                | D             | E              | F | G | H       | I           |
|----|---|-----------|------------------|---------------|----------------|---|---|---------|-------------|
| 33 | Element/Compound                                | Atm. Wt.  | Mass In Canister | Element Wt. % | Compound Wt. % |   |   | g/mole  | Fractions   |
| 34 | Group   |           | (gram)           |               | (note a)       |   |   |         | of Element  |
| 35 |   |           |                  |               |                |   |   |         |             |
| 36 | Al <sub>2</sub> O <sub>3</sub>                  |           | 66607.2          |               |                |   |   |         |             |
| 37 | Al  | 26.981538 |                  | 2.095832745   |                |   |   |         | 0.529250693 |
| 38 | O   |           |                  | 1.864167255   |                |   |   |         | 0.470749307 |
| 39 | Total g/mole                                    |           |                  |               |                |   |   | 101.961 |             |
| 40 | Total Compound                                  |           |                  |               | 3.96           |   |   |         |             |
| 41 |   |           |                  |               |                |   |   |         |             |
| 42 | BaSO <sub>4</sub>                               |           | 2354.8           |               |                |   |   |         |             |
| 43 | Ba  | 137.327   |                  | 0.082375983   |                |   |   |         | 0.588399876 |
| 44 | S   | 32.066    |                  | 0.019234879   |                |   |   |         | 0.137391994 |
| 45 | O   | 15.9994   |                  | 0.038389138   |                |   |   |         | 0.27420813  |
| 46 | Total g/mole                                    |           |                  |               |                |   |   | 233.391 |             |
| 47 | Total Compound                                  |           |                  |               | 0.14           |   |   |         |             |
| 48 |   |           |                  |               |                |   |   |         |             |
| 49 | Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> |           | 1177.4           |               |                |   |   |         |             |
| 50 | Ca  | 40.078    |                  | 0.027134144   |                |   |   |         | 0.387630633 |
| 51 | P   | 30.973762 |                  | 0.013980181   |                |   |   |         | 0.199716869 |
| 52 | O   | 15.9994   |                  | 0.028885675   |                |   |   |         | 0.412652498 |
| 53 | Total g/mole                                    |           |                  |               |                |   |   | 310.177 |             |
| 54 | Total Compound                                  |           |                  |               | 0.07           |   |   |         |             |
| 55 |   |           |                  |               |                |   |   |         |             |
| 56 | CaO   |           | 14297            |               |                |   |   |         |             |
| 57 | Ca  | 40.078    |                  | 0.607487152   |                |   |   |         | 0.714690767 |
| 58 | O   | 15.9994   |                  | 0.242512848   |                |   |   |         | 0.285309233 |
| 59 | Total g/mole                                    |           |                  |               |                |   |   | 56.0774 |             |
| 60 | Total Compound                                  |           |                  |               | 0.85           |   |   |         |             |
| 61 |   |           |                  |               |                |   |   |         |             |
| 62 | CaSO <sub>4</sub>                               |           | 1345.6           |               |                |   |   |         |             |
| 63 | Ca  | 40.078    |                  | 0.023550774   |                |   |   |         | 0.28438467  |
| 64 | S   | 32.066    |                  | 0.018842734   |                |   |   |         | 0.235534179 |
| 65 | O   | 15.9994   |                  | 0.037606492   |                |   |   |         | 0.470081151 |
| 66 | Total g/mole                                    |           |                  |               |                |   |   | 136.142 |             |
| 67 | Total Compound                                  |           |                  |               | 0.08           |   |   |         |             |
| 68 |   |           |                  |               |                |   |   |         |             |
| 69 | Cr <sub>2</sub> O <sub>3</sub>                  |           | 2018.4           |               |                |   |   |         |             |
| 70 | Cr  | 51.9961   |                  | 0.082104291   |                |   |   |         | 0.684202423 |
| 71 | O   | 15.9994   |                  | 0.037895709   |                |   |   |         | 0.315797577 |
| 72 | Total g/mole                                    |           |                  |               |                |   |   | 151.99  |             |
| 73 | Total Compound                                  |           |                  |               | 0.12           |   |   |         |             |
| 74 |   |           |                  |               |                |   |   |         |             |
| 75 | CuO   |           | 3195.8           |               |                |   |   |         |             |

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|     | A                               | B         | C        | D           | E    | F | G | H       | I           |
|-----|---------------------------------|-----------|----------|-------------|------|---|---|---------|-------------|
| 76  | Cu                              | 63.546    |          | 0.151784264 |      |   |   |         | 0.798864548 |
| 77  | O                               | 15.9994   |          | 0.038215736 |      |   |   |         | 0.201135452 |
| 78  | Total g/mole                    |           |          |             |      |   |   | 79.5454 |             |
| 79  | Total Compound                  |           |          |             | 0.19 |   |   |         |             |
| 80  |                                 |           |          |             |      |   |   |         |             |
| 81  | Fe <sub>2</sub> O <sub>3</sub>  |           | 118412.8 |             |      |   |   |         |             |
| 82  | Fe                              | 55.847    |          | 4.924008561 |      |   |   |         | 0.699433034 |
| 83  | O                               | 15.9994   |          | 2.115991439 |      |   |   |         | 0.300566966 |
| 84  | Total g/mole                    |           |          |             |      |   |   | 159.692 |             |
| 85  | Total Compound                  |           |          |             | 7.04 |   |   |         |             |
| 86  |                                 |           |          |             |      |   |   |         |             |
| 87  | FeO                             |           | 52478.4  |             |      |   |   |         |             |
| 88  | Fe                              | 55.847    |          | 2.425210449 |      |   |   |         | 0.777311041 |
| 89  | O                               | 15.9994   |          | 0.694789551 |      |   |   |         | 0.222688959 |
| 90  | Total g/mole                    |           |          |             |      |   |   | 71.8464 |             |
| 91  | Total Compound                  |           |          |             | 3.12 |   |   |         |             |
| 92  |                                 |           |          |             |      |   |   |         |             |
| 93  | K <sub>2</sub> O                |           | 60215.6  |             |      |   |   |         |             |
| 94  | K                               | 39.0983   |          | 2.971929042 |      |   |   |         | 0.830147777 |
| 95  | O                               | 15.9994   |          | 0.608070958 |      |   |   |         | 0.169852223 |
| 96  | Total g/mole                    |           |          |             |      |   |   | 84.196  |             |
| 97  | Total Compound                  |           |          |             | 3.58 |   |   |         |             |
| 98  |                                 |           |          |             |      |   |   |         |             |
| 99  | MgO                             |           | 22875.2  |             |      |   |   |         |             |
| 100 | Mg                              | 24.305    |          | 0.62012882  |      |   |   |         | 0.603035897 |
| 101 | O                               | 15.9994   |          | 0.53967118  |      |   |   |         | 0.396964103 |
| 102 | Total g/mole                    |           |          |             |      |   |   | 40.3044 |             |
| 103 | Total Compound                  |           |          |             | 1.36 |   |   |         |             |
| 104 |                                 |           |          |             |      |   |   |         |             |
| 105 | MnO                             |           | 33640    |             |      |   |   |         |             |
| 106 | Mn                              | 54.93805  |          | 1.548915277 |      |   |   |         | 0.774457638 |
| 107 | O                               | 15.9994   |          | 0.451084723 |      |   |   |         | 0.225542362 |
| 108 | Total g/mole                    |           |          |             |      |   |   | 70.9375 |             |
| 109 | Total Compound                  |           |          |             | 2    |   |   |         |             |
| 110 |                                 |           |          |             |      |   |   |         |             |
| 111 | Na <sub>2</sub> O               |           | 185020   |             |      |   |   |         |             |
| 112 | Na                              | 22.989769 |          | 8.160432146 |      |   |   |         | 0.741857468 |
| 113 | O                               | 15.9994   |          | 2.839567854 |      |   |   |         | 0.258142532 |
| 114 | Total g/mole                    |           |          |             |      |   |   | 61.9789 |             |
| 115 | Total Compound                  |           |          |             | 11   |   |   |         |             |
| 116 |                                 |           |          |             |      |   |   |         |             |
| 117 | Na <sub>2</sub> SO <sub>4</sub> |           | 6055.2   |             |      |   |   |         |             |
| 118 | Na                              | 22.989769 |          | 0.116532442 |      |   |   |         | 0.323701227 |

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|     | A                | B         | C        | D           | E     | F | G | H       | I           |
|-----|------------------|-----------|----------|-------------|-------|---|---|---------|-------------|
| 119 | S                | 32.066    |          | 0.081269396 |       |   |   |         | 0.225748322 |
| 120 | O                | 15.9994   |          | 0.162198163 |       |   |   |         | 0.450550452 |
| 121 | Total g/mole     |           |          |             |       |   |   | 142.043 |             |
| 122 | Total Compound   |           |          |             | 0.36  |   |   |         |             |
| 123 |                  |           |          |             |       |   |   |         |             |
| 124 | NaCl             |           | 3195.8   |             |       |   |   |         |             |
| 125 | Na               | 22.989769 |          | 0.074741129 |       |   |   |         | 0.393374363 |
| 126 | Cl               | 35.4527   |          | 0.115258871 |       |   |   |         | 0.606625637 |
| 127 | Total g/mole     |           |          |             |       |   |   | 58.4425 |             |
| 128 | Total Compound   |           |          |             | 0.19  |   |   |         |             |
| 129 |                  |           |          |             |       |   |   |         |             |
| 130 | NaF              |           | 1177.4   |             |       |   |   |         |             |
| 131 | Na               | 22.989769 |          | 0.038327075 |       |   |   |         | 0.547529645 |
| 132 | F                | 18.998403 |          | 0.031672925 |       |   |   |         | 0.452470355 |
| 133 | Total g/mole     |           |          |             |       |   |   | 41.9882 |             |
| 134 | Total Compound   |           |          |             | 0.07  |   |   |         |             |
| 135 |                  |           |          |             |       |   |   |         |             |
| 136 | NiO              |           | 15842.6  |             |       |   |   |         |             |
| 137 | Ni               | 58.69     |          | 0.730782414 |       |   |   |         | 0.785787541 |
| 138 | O                | 15.9994   |          | 0.199217586 |       |   |   |         | 0.214212459 |
| 139 | Total g/mole     |           |          |             |       |   |   | 74.6894 |             |
| 140 | Total Compound   |           |          |             | 0.93  |   |   |         |             |
| 141 |                  |           |          |             |       |   |   |         |             |
| 142 | PbS              |           | 1177.4   |             |       |   |   |         |             |
| 143 | Pb               | 207.2     |          | 0.060618726 |       |   |   |         | 0.865981794 |
| 144 | S                | 32.066    |          | 0.009381274 |       |   |   |         | 0.134018206 |
| 145 | Total g/mole     |           |          |             |       |   |   | 239.266 |             |
| 146 | Total Compound   |           |          |             | 0.07  |   |   |         |             |
| 147 |                  |           |          |             |       |   |   |         |             |
| 148 | SiO <sub>2</sub> |           | 766487.4 |             |       |   |   |         |             |
| 149 | Si               | 28.0855   |          | 21.30100933 |       |   |   |         | 0.467434921 |
| 150 | O                | 15.9994   |          | 24.26899067 |       |   |   |         | 0.532565079 |
| 151 | Total g/mole     |           |          |             |       |   |   | 60.0843 |             |
| 152 | Total Compound   |           |          |             | 45.57 |   |   |         |             |
| 153 |                  |           |          |             |       |   |   |         |             |
| 154 | ThO <sub>2</sub> |           | 3532.2   |             |       |   |   |         |             |
| 155 | Th               | 232.0381  |          | 0.184549966 |       |   |   |         | 0.878809363 |
| 156 | O                | 15.9994   |          | 0.025450034 |       |   |   |         | 0.121190637 |
| 157 | Total g/mole     |           |          |             |       |   |   | 264.037 |             |
| 158 | Total Compound   |           |          |             | 0.21  |   |   |         |             |
| 159 |                  |           |          |             |       |   |   |         |             |
| 160 | TiO <sub>2</sub> |           | 16651.8  |             |       |   |   |         |             |
| 161 | Ti               | 47.88     |          | 0.593414022 |       |   |   |         | 0.599408103 |

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|     | A  | B         | C       | D           | E    | F | G | H       | I           |
|-----|--|-----------|---------|-------------|------|---|---|---------|-------------|
| 162 | O  | 15.9994   |         | 0.396585978 |      |   |   |         | 0.400591897 |
| 163 | Total g/mole                                 |           |         |             |      |   |   | 79.8788 |             |
| 164 | Total Compound                               |           |         |             | 0.99 |   |   |         |             |
| 165 |  |           |         |             |      |   |   |         |             |
| 166 | NaAlSi <sub>3</sub> O <sub>8</sub> (Zeolite) |           | 28089.4 |             |      |   |   |         |             |
| 167 | Na   | 22.989769 |         | 0.18993351  |      |   |   |         | 0.113732641 |
| 168 | Al   | 26.981539 |         | 0.22291213  |      |   |   |         | 0.133480317 |
| 169 | Si   | 28.0855   |         | 0.464065349 |      |   |   |         | 0.277883442 |
| 170 | O  | 15.9994   |         | 0.793089011 |      |   |   |         | 0.4749036   |
| 171 | Total g/mole                                 |           |         |             |      |   |   | 202.139 |             |
| 172 | Total Compound                               |           |         |             | 1.67 |   |   |         |             |
| 173 |  |           |         |             |      |   |   |         |             |
| 174 | ZnO  |           | 1345.6  |             |      |   |   |         |             |
| 175 | Zn   | 65.39     |         | 0.064273726 |      |   |   |         | 0.803421576 |
| 176 | O  | 15.9994   |         | 0.015726274 |      |   |   |         | 0.196578424 |
| 177 | Total g/mole                                 |           |         |             |      |   |   | 81.3694 |             |
| 178 | Total Compound                               |           |         |             | 0.08 |   |   |         |             |

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|     | A   | B               | C                       | D                    | E                    | F                      | G                      | H             | I                 |
|-----|---|-----------------|-------------------------|----------------------|----------------------|------------------------|------------------------|---------------|-------------------|
| 179 |   |                 |                         |                      |                      |                        |                        |               |                   |
| 180 | <b>Element/Compound</b>                                     | <b>Atm. Wt.</b> | <b>Mass in Canister</b> | <b>Element Wt. %</b> | <b>Element Moles</b> | <b>Moles of Oxygen</b> | <b>Wt. % of Oxygen</b> | <b>g/mole</b> | <b>Fractions</b>  |
| 181 | <b>Group</b>  |                 |                         |                      |                      |                        |                        |               | <b>of Element</b> |
| 182 |   |                 |                         |                      |                      |                        |                        |               |                   |
| 183 | B <sub>2</sub> O <sub>3</sub>                               |                 | 172.9096                |                      | 0.295316352          | 0.442974527            | 7.087326652            |               |                   |
| 184 | B   | 10.811028       |                         |                      |                      |                        |                        |               | 0.310571337       |
| 185 | B-10  | 10.012937       | 9.897557782             | 0.588439821          | 0.058767954          | 0.088151931            | 1.410378004            |               |                   |
| 186 | B-11  | 11.009305       | 43.80320793             | 2.604233527          | 0.236548398          | 0.354822596            | 5.676948648            |               |                   |
| 187 | O   | 15.9994         |                         | 7.087326652          |                      |                        | 7.087326652            |               | 0.689428663       |
| 188 | Total g/mole  |                 |                         |                      |                      |                        |                        | 69.6203       |                   |
| 189 | Total Compound (note a)                                     |                 |                         | 10.28                |                      |                        |                        |               |                   |
| 190 |   |                 |                         |                      |                      |                        |                        |               |                   |
| 191 | Li <sub>2</sub> O   |                 | 53.1512                 |                      | 0.211503689          | 0.105751844            | 1.69196606             |               |                   |
| 192 | Li  | 6.9409378       |                         |                      |                      |                        |                        |               | 0.464567703       |
| 193 | Li-6  | 6.015122        | 1.604906151             | 0.095416537          | 0.015862777          | 0.007931388            | 0.126897454            |               |                   |
| 194 | Li-7  | 7.0160039       | 23.08742472             | 1.372617403          | 0.195640912          | 0.097820456            | 1.565068605            |               |                   |
| 195 | O   | 15.9994         |                         | 1.69196606           |                      |                        | 1.69196606             |               | 0.535432297       |
| 196 | Total g/mole  |                 |                         |                      |                      |                        |                        | 29.8813       |                   |
| 197 | Total Compound (note a)                                     |                 |                         | 3.16                 |                      |                        |                        |               |                   |
| 198 |   |                 |                         |                      |                      |                        |                        |               |                   |
| 199 | Ag (note a)   |                 |                         | 0.05                 |                      |                        |                        |               |                   |
| 200 | Other (note a)  |                 |                         | 0.58                 |                      |                        |                        |               |                   |
| 201 |   |                 |                         |                      |                      |                        |                        |               |                   |
| 202 | Note a: The total wt.% come from Ref. 1 in the main report. |                 |                         |                      |                      |                        |                        |               |                   |
| 203 |   |                 |                         |                      |                      |                        |                        |               |                   |

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|     | A              | B | C                            | D                        | E              | F                            | G                        | H              | I |
|-----|----------------|---|------------------------------|--------------------------|----------------|------------------------------|--------------------------|----------------|---|
| 204 | <b>SUMMARY</b> |   |                              |                          |                |                              |                          |                |   |
| 205 |                |   |                              |                          |                |                              |                          |                |   |
| 206 | <b>Element</b> |   | <b>Wt. %, Not Normalized</b> | <b>Wt. %, Normalized</b> | <b>Element</b> | <b>Wt. %, Not Normalized</b> | <b>Wt. %, Normalized</b> |                |   |
| 207 |                |   |                              |                          |                |                              |                          |                |   |
| 208 | O              |   | 4.4519E+01                   | 4.4770E+01               | Ni             | 7.3078E-01                   | 7.3490E-01               |                |   |
| 209 | U-234          |   | 3.2610E-04                   | 3.2794E-04               | Pb             | 6.0619E-02                   | 6.0961E-02               |                |   |
| 210 | U-235          |   | 4.3270E-03                   | 4.3514E-03               | Si             | 2.1765E+01                   | 2.1888E+01               |                |   |
| 211 | U-236          |   | 1.0357E-03                   | 1.0415E-03               | Th             | 1.8455E-01                   | 1.8559E-01               |                |   |
| 212 | U-238          |   | 1.8561E+00                   | 1.8666E+00               | Ti             | 5.9341E-01                   | 5.9676E-01               |                |   |
| 213 | Pu-238         |   | 5.1528E-03                   | 5.1819E-03               | Zn             | 6.4274E-02                   | 6.4636E-02               |                |   |
| 214 | Pu-239         |   | 1.2342E-02                   | 1.2412E-02               | B-10           | 5.8844E-01                   | 5.9176E-01               |                |   |
| 215 | Pu-240         |   | 2.2646E-03                   | 2.2773E-03               | B-11           | 2.6042E+00                   | 2.6189E+00               |                |   |
| 216 | Pu-241         |   | 9.6314E-04                   | 9.6857E-04               | Li-6           | 9.5417E-02                   | 9.5955E-02               |                |   |
| 217 | Pu-242         |   | 1.9061E-04                   | 1.9168E-04               | Li-7           | 1.3726E+00                   | 1.3804E+00               |                |   |
| 218 | Cs-133         |   | 4.0718E-02                   | 4.0948E-02               | F              | 3.1673E-02                   | 3.1852E-02               |                |   |
| 219 | Cs-135         |   | 5.1326E-03                   | 5.1615E-03               | Cu             | 1.5178E-01                   | 1.5264E-01               |                |   |
| 220 | Ba-137         |   | 1.1204E-01                   | 1.1267E-01               | Fe             | 7.3492E+00                   | 7.3907E+00               |                |   |
| 221 | Al             |   | 2.3187E+00                   | 2.3318E+00               | K              | 2.9719E+00                   | 2.9887E+00               |                |   |
| 222 | S              |   | 1.2873E-01                   | 1.2945E-01               | Mg             | 8.2013E-01                   | 8.2475E-01               |                |   |
| 223 | Ca             |   | 6.5817E-01                   | 6.6188E-01               | Mn             | 1.5489E+00                   | 1.5577E+00               |                |   |
| 224 | P              |   | 1.3980E-02                   | 1.4059E-02               | Na             | 8.5800E+00                   | 8.6284E+00               |                |   |
| 225 | Cr             |   | 8.2104E-02                   | 8.2567E-02               | Cl             | 1.1526E-01                   | 1.1591E-01               |                |   |
| 226 | Ag             |   | 5.0000E-02                   | 5.0282E-02               |                |                              |                          |                |   |
| 227 |                |   |                              |                          |                |                              |                          |                |   |
| 228 | Sub Col Total  |   | 4.9811E+01                   | 5.0092E+01               |                | 4.9628E+01                   | 4.9908E+01               |                |   |
| 229 | Total          |   | 9.9439E+01                   | 1.0000E+02               |                |                              |                          |                |   |
| 230 | Other          |   | 5.8000E-01                   |                          |                |                              |                          |                |   |
| 231 | Check Total    |   | 1.0000E+02                   |                          |                |                              |                          | 100            |   |
| 232 |                |   | From elements                |                          |                |                              |                          | From compounds |   |
| 233 |                |   |                              |                          |                |                              |                          |                |   |



Attachment II SRS HLW Glass Chemical Composition Calculation Formulas

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|    | A                                   | B          | C                             | D                              | E                   | F               | G                      | H | I |
|----|-------------------------------------|------------|-------------------------------|--------------------------------|---------------------|-----------------|------------------------|---|---|
| 1  | Element/Compound                    | Atom Wt.   | Mass in Calculator (gram)     | Element Wt. % (in 100 g glass) | Element Moles       | Moles of Oxygen | Wt. % of Oxygen        |   |   |
| 2  | Group                               |            |                               |                                |                     |                 |                        |   |   |
| 3  |                                     |            |                               |                                |                     |                 |                        |   |   |
| 4  | Oxygen                              | 15.9994    |                               |                                |                     |                 |                        |   |   |
| 5  |                                     |            |                               |                                |                     |                 |                        |   |   |
| 6  | U-234                               | 234.040904 | 5.485                         | $=((C6)/(1682*1000))*100$      | $=D6/68$            | $=E6*(8/3)$     | $=B4*F6$               |   |   |
| 7  | U-235                               | 235.043915 | 72.78                         | $=((C7)/(1682*1000))*100$      | $=D7/67$            | $=E7*(8/3)$     | $=B4*F7$               |   |   |
| 8  | U-238                               | 238.04556  | 17.42                         | $=((C8)/(1682*1000))*100$      | $=D8/68$            | $=E8*(8/3)$     | $=B4*F8$               |   |   |
| 9  | U-238                               | 238.05076  | 31220                         | $=((C9)/(1682*1000))*100$      | $=D9/69$            | $=E9*(8/3)$     | $=B4*F9$               |   |   |
| 10 | Total Unstable Mass                 |            | $=(C6+C7+C8+C9)/1000$         | $=SUM(D6:D9)$                  |                     |                 | $=SUM(G6:G9)$          |   |   |
| 11 | Total Oxygen                        |            |                               |                                |                     |                 | $=G6+G7+G8+G9$         |   |   |
| 12 | Total U <sub>2</sub> O <sub>8</sub> |            |                               | $=2.2$                         |                     |                 |                        |   |   |
| 13 |                                     |            |                               |                                |                     |                 |                        |   |   |
| 14 | Pu-238                              | 238.04955  | 86.67                         | $=((C14)/(1682*1000))*100$     | $=D14/614$          | $=E14*(2/1)$    | $=B4*F14$              |   |   |
| 15 | Pu-239                              | 239.052146 | 207.6                         | $=((C15)/(1682*1000))*100$     | $=D15/615$          | $=E15*(2/1)$    | $=B4*F15$              |   |   |
| 16 | Pu-240                              | 240.05381  | 38.09                         | $=((C16)/(1682*1000))*100$     | $=D16/616$          | $=E16*(2/1)$    | $=B4*F16$              |   |   |
| 17 | Pu-241                              | 241.05584  | 16.2                          | $=((C17)/(1682*1000))*100$     | $=D17/617$          | $=E17*(2/1)$    | $=B4*F17$              |   |   |
| 18 | Pu-242                              | 242.058725 | 3.206                         | $=((C18)/(1682*1000))*100$     | $=D18/618$          | $=E18*(2/1)$    | $=B4*F18$              |   |   |
| 19 | Total Unstable Mass                 |            | $=(C14+C15+C16+C17+C18)/1000$ | $=SUM(D14:D18)$                |                     |                 |                        |   |   |
| 20 | Total Oxygen                        |            |                               |                                |                     |                 | $=G14+G15+G16+G17+G18$ |   |   |
| 21 |                                     |            |                               |                                |                     |                 |                        |   |   |
| 22 | Ca-135                              | 134.90597  | 86.33                         | $=((C22)/(1682*1000))*100$     | $=D22/622$          | $=E22*(1/2)$    | $=B4*F22$              |   |   |
| 23 | Ca-137                              | 136.9071   | 498.9                         | $=((C23)/(1682*1000))*100$     | $=D23/623$          | $=E23*(1/2)$    | $=B4*F23$              |   |   |
| 24 | Unstable Ca-Total                   |            |                               | $=SUM(D22:D23)+SUM(G22:G23)$   |                     |                 |                        |   |   |
| 25 | Total Ca <sub>2</sub> O             |            |                               | 0.06                           |                     |                 |                        |   |   |
| 26 | Stable Oxide                        |            |                               | $=D25-D24$                     |                     |                 |                        |   |   |
| 27 | Stable Oxide Mass                   |            | $=(D26*(1682)/100)*1000$      |                                |                     |                 |                        |   |   |
| 28 | Total Unstable Mass                 |            | $=(C22+C23)/1000$             |                                |                     |                 |                        |   |   |
| 29 | Ca-133                              | 132.90544  |                               | $=H26*((2*B29)/(2*B29+B4))$    | $=2*H26/(2*B29+B4)$ | $=E29/2$        | $=F29*B4$              |   |   |
| 30 |                                     |            |                               |                                |                     |                 |                        |   |   |
| 31 | Ba-137                              |            |                               | $=D23$                         |                     |                 |                        |   |   |
| 32 | (same as Ca137)                     |            |                               |                                |                     |                 |                        |   |   |
| 33 |                                     |            |                               |                                |                     |                 |                        |   |   |

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|    | A   | B         | C                 | D                   | E              | F | G | H                  | I          |
|----|---|-----------|-------------------|---------------------|----------------|---|---|--------------------|------------|
| 34 | Element/Compound                                | Atom Wt.  | Mols in Canister  | Element Wt. %       | Compound Wt. % |   |   | gmole              | Fraction   |
| 35 | Group   |           | (gram)            |                     |                |   |   |                    | of Element |
| 36 |   |           |                   |                     |                |   |   |                    |            |
| 37 | Al <sub>2</sub> O <sub>3</sub>                  |           | =3.96*1682/1000   |                     |                |   |   |                    |            |
| 38 | Al  | 26.981538 |                   | =(38*C37)/1682*1000 |                |   |   |                    | =2*B38/H39 |
| 39 | Total gmole                                     |           |                   |                     |                |   |   | =2*B38+3*B4        |            |
| 40 | O   |           |                   | =(40*C37)/1682*1000 |                |   |   |                    | =3*B4/H39  |
| 41 |   |           |                   |                     | =SUM(D38:D40)  |   |   |                    |            |
| 42 | BaSO <sub>4</sub>                               |           | =(0.14*1682)/1000 |                     |                |   |   |                    |            |
| 43 | Ba  | 137.327   |                   | =(43*C42)/1682*1000 |                |   |   |                    | =B43/H46   |
| 44 | S   | 32.066    |                   | =(44*C42)/1682*1000 |                |   |   |                    | =B44/H46   |
| 45 | O   | =B4       |                   | =(45*C42)/1682*1000 |                |   |   |                    | =4*B45/H46 |
| 46 | Total gmole                                     |           |                   |                     | =SUM(D43:D45)  |   |   | =B43+B44+4*B4      |            |
| 47 |   |           |                   |                     |                |   |   |                    |            |
| 48 | Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> |           | =0.07*1682/1000   |                     |                |   |   |                    |            |
| 49 | Ca  | 40.078    |                   | =(49*C48)/1682*1000 |                |   |   |                    | =3*B49/H52 |
| 50 | P   | 30.973762 |                   | =(50*C48)/1682*1000 |                |   |   |                    | =2*B50/H52 |
| 51 | O   | =B4       |                   | =(51*C48)/1682*1000 |                |   |   |                    | =8*B51/H52 |
| 52 | Total gmole                                     |           |                   |                     | =SUM(D49:D51)  |   |   | =3*B49+2*B50+8*B51 |            |
| 53 |   |           |                   |                     |                |   |   |                    |            |
| 54 | CaO   |           | =0.85*1682/1000   |                     |                |   |   |                    |            |
| 55 | Ca  | 40.078    |                   | =(55*C54)/1682*1000 |                |   |   |                    | =B55/H57   |
| 56 | O   | =B4       |                   | =(56*C54)/1682*1000 |                |   |   |                    | =B56/H57   |
| 57 | Total gmole                                     |           |                   |                     | =SUM(D54:D56)  |   |   | =B55+B56           |            |
| 58 |   |           |                   |                     |                |   |   |                    |            |
| 59 | CaSO <sub>4</sub>                               |           | =0.08*1682/1000   |                     |                |   |   |                    |            |
| 60 | Ca  | 40.078    |                   | =(60*C59)/1682*1000 |                |   |   |                    | =B60/H63   |
| 61 | S   | 32.066    |                   | =(61*C59)/1682*1000 |                |   |   |                    | =B61/H63   |
| 62 | O   | =B4       |                   | =(62*C59)/1682*1000 |                |   |   |                    | =4*B62/H63 |
| 63 | Total gmole                                     |           |                   |                     | =SUM(D60:D62)  |   |   | =B60+B61+4*B62     |            |
| 64 |   |           |                   |                     |                |   |   |                    |            |
| 65 | Cr <sub>2</sub> O <sub>3</sub>                  |           | =0.12*1682/1000   |                     |                |   |   |                    |            |
| 66 | Cr  | 51.9961   |                   | =(66*C65)/1682*1000 |                |   |   |                    | =2*B66/H68 |
| 67 | O   | =B4       |                   | =(67*C65)/1682*1000 |                |   |   |                    | =3*B67/H68 |
| 68 | Total gmole                                     |           |                   |                     | =SUM(D65:D67)  |   |   | =2*B66+3*B67       |            |
| 69 |   |           |                   |                     |                |   |   |                    |            |
| 70 | CuO   |           | =0.19*1682/1000   |                     |                |   |   |                    |            |
| 71 | Cu  | 63.546    |                   | =(71*C70)/1682*1000 |                |   |   |                    | =B71/H73   |
| 72 | O   | =B4       |                   | =(72*C70)/1682*1000 |                |   |   |                    | =B72/H73   |
| 73 | Total gmole                                     |           |                   |                     | =SUM(D70:D72)  |   |   | =B71+B72           |            |
| 74 |   |           |                   |                     |                |   |   |                    |            |
| 75 | Fe <sub>2</sub> O <sub>3</sub>                  |           | =7.04*1682/1000   |                     |                |   |   |                    |            |
| 76 | Fe  | 55.847    |                   | =(76*C75)/1682*1000 |                |   |   |                    | =2*B76/H78 |
| 77 | O   | =B4       |                   | =(77*C75)/1682*1000 |                |   |   |                    | =3*B77/H78 |
| 78 | Total gmole                                     |           |                   |                     | =SUM(D75:D77)  |   |   | =2*B76+3*B77       |            |
| 79 |   |           |                   |                     |                |   |   |                    |            |
| 80 | FeO   |           | =3.12*1682/1000   |                     |                |   |   |                    |            |
| 81 | Fe  | 55.847    |                   | =(81*C80)/1682*1000 |                |   |   |                    | =B81/H83   |
| 82 | O   | =B4       |                   | =(82*C80)/1682*1000 |                |   |   |                    | =B82/H83   |
| 83 | Total gmole                                     |           |                   |                     | =SUM(D80:D82)  |   |   | =B81+B82           |            |
| 84 |   |           |                   |                     |                |   |   |                    |            |
| 85 | K <sub>2</sub> O                                |           | =3.58*1682/1000   |                     |                |   |   |                    |            |
| 86 | K   | 39.0983   |                   | =(86*C85)/1682*1000 |                |   |   |                    | =2*B86/H88 |
| 87 | O   | =B4       |                   | =(87*C85)/1682*1000 |                |   |   |                    | =B87/H88   |
| 88 | Total gmole                                     |           |                   |                     | =SUM(D85:D87)  |   |   | =2*B86+B87         |            |
| 89 |   |           |                   |                     |                |   |   |                    |            |
| 90 | MgO   |           | =1.36*1682/1000   |                     |                |   |   |                    |            |
| 91 | Mg  | 24.305    |                   | =(91*C90)/1682*1000 |                |   |   |                    | =B91/H93   |
| 92 | O   | =B4       |                   | =(92*C90)/1682*1000 |                |   |   |                    | =B92/H93   |
| 93 | Total gmole                                     |           |                   |                     | =SUM(D90:D92)  |   |   | =B91+B92           |            |
| 94 |   |           |                   |                     |                |   |   |                    |            |
| 95 | MnO   |           | =2*1682/1000      |                     |                |   |   |                    |            |
| 96 | Mn  | 54.93805  |                   | =(96*C95)/1682*1000 |                |   |   |                    | =B96/H98   |

|     | A   | B          | C                | D                      | E               | F | G | H                        | I            |
|-----|---|------------|------------------|------------------------|-----------------|---|---|--------------------------|--------------|
| 97  | O   | =B4        |                  | =(197*C95)/1682*1000   |                 |   |   |                          | =B97A198     |
| 98  | Total g/mole                                |            |                  |                        | =SUM(D95:D97)   |   |   | =B96+B97                 |              |
| 99  |   |            |                  |                        |                 |   |   |                          |              |
| 100 | Na <sub>2</sub> O                           |            | =11*1682/1000    |                        |                 |   |   |                          |              |
| 101 | Na  | 22.989768  |                  | =(1101*C100)/1682*1000 |                 |   |   |                          | =2*B101A1103 |
| 102 | O   | =B4        |                  | =(1102*C100)/1682*1000 |                 |   |   |                          | =B102A1103   |
| 103 | Total g/mole                                |            |                  |                        | =SUM(D100:D102) |   |   | =2*B101+B102             |              |
| 104 |   |            |                  |                        |                 |   |   |                          |              |
| 105 | Na <sub>2</sub> SO <sub>4</sub>             |            | =0.36*1682/1000  |                        |                 |   |   |                          |              |
| 106 | Na  | 22.989768  |                  | =(1106*C105)/1682*1000 |                 |   |   |                          | =2*B106A1109 |
| 107 | S   | 32.066     |                  | =(1107*C105)/1682*1000 |                 |   |   |                          | =B107A1109   |
| 108 | O   | =B4        |                  | =(1108*C105)/1682*1000 |                 |   |   |                          | =4*B108A1109 |
| 109 | Total g/mole                                |            |                  |                        | =SUM(D106:D108) |   |   | =2*B106+B107+4*B108      |              |
| 110 |   |            |                  |                        |                 |   |   |                          |              |
| 111 | NaCl  |            | =0.19*1682/1000  |                        |                 |   |   |                          |              |
| 112 | Na  | 22.989768  |                  | =(1112*C111)/1682*1000 |                 |   |   |                          | =B112A1114   |
| 113 | Cl  | 35.4527    |                  | =(1113*C111)/1682*1000 |                 |   |   |                          | =B113A1114   |
| 114 | Total g/mole                                |            |                  |                        | =SUM(D111:D113) |   |   | =B112+B113               |              |
| 115 |   |            |                  |                        |                 |   |   |                          |              |
| 116 | NaF   |            | =0.07*1682/1000  |                        |                 |   |   |                          |              |
| 117 | Na  | 22.989768  |                  | =(1117*C116)/1682*1000 |                 |   |   |                          | =B117A1119   |
| 118 | F   | 18.9984032 |                  | =(1118*C116)/1682*1000 |                 |   |   |                          | =B118A1119   |
| 119 | Total g/mole                                |            |                  |                        | =SUM(D116:D118) |   |   | =B117+B118               |              |
| 120 |   |            |                  |                        |                 |   |   |                          |              |
| 121 | NiO   |            | =0.93*1682/1000  |                        |                 |   |   |                          |              |
| 122 | Ni  | 58.69      |                  | =(1122*C121)/1682*1000 |                 |   |   |                          | =B122A1124   |
| 123 | O   | =B4        |                  | =(1123*C121)/1682*1000 |                 |   |   |                          | =B123A1124   |
| 124 | Total g/mole                                |            |                  |                        | =SUM(D121:D123) |   |   | =B122+B123               |              |
| 125 |   |            |                  |                        |                 |   |   |                          |              |
| 126 | PbS   |            | =0.07*1682/1000  |                        |                 |   |   |                          |              |
| 127 | Pb  | 207.2      |                  | =(1127*C126)/1682*1000 |                 |   |   |                          | =B127A1128   |
| 128 | S   | 32.066     |                  | =(1128*C126)/1682*1000 |                 |   |   |                          | =B128A1129   |
| 129 | Total g/mole                                |            |                  |                        | =SUM(D126:D128) |   |   | =B127+B128               |              |
| 130 |   |            |                  |                        |                 |   |   |                          |              |
| 131 | SiO <sub>2</sub>                            |            | =45.67*1682/1000 |                        |                 |   |   |                          |              |
| 132 | Si  | 28.0855    |                  | =(1132*C131)/1682*1000 |                 |   |   |                          | =B132A1134   |
| 133 | O   | =B4        |                  | =(1133*C131)/1682*1000 |                 |   |   |                          | =2*B133A1134 |
| 134 | ThO <sub>2</sub>                            |            |                  |                        | =SUM(D131:D133) |   |   | =B132+2*B133             |              |
| 135 |   |            |                  |                        |                 |   |   |                          |              |
| 136 | ThO <sub>2</sub>                            |            | =0.21*1682/1000  |                        |                 |   |   |                          |              |
| 137 | Th  | 232.0381   |                  | =(1137*C136)/1682*1000 |                 |   |   |                          | =B137A1139   |
| 138 | O   | =B4        |                  | =(1138*C136)/1682*1000 |                 |   |   |                          | =2*B138A1139 |
| 139 | Total g/mole                                |            |                  |                        | =SUM(D136:D138) |   |   | =B137+2*B138             |              |
| 140 |   |            |                  |                        |                 |   |   |                          |              |
| 141 | TiO <sub>2</sub>                            |            | =0.99*1682/1000  |                        |                 |   |   |                          |              |
| 142 | Ti  | 47.88      |                  | =(1142*C141)/1682*1000 |                 |   |   |                          | =B142A1144   |
| 143 | O   | =B4        |                  | =(1143*C141)/1682*1000 |                 |   |   |                          | =2*B143A1144 |
| 144 | Total g/mole                                |            |                  |                        | =SUM(D141:D143) |   |   | =B142+2*B143             |              |
| 145 |   |            |                  |                        |                 |   |   |                          |              |
| 146 | NaAlSi <sub>3</sub> O <sub>8</sub> (Zeo/Me) |            | =1.67*1682/1000  |                        |                 |   |   |                          |              |
| 147 | Na  | 22.989768  |                  | =(1147*C146)/1682*1000 |                 |   |   |                          | =B147A1151   |
| 148 | Al  | 26.9815389 |                  | =(1148*C146)/1682*1000 |                 |   |   |                          | =B148A1151   |
| 149 | Si  | 28.0855    |                  | =(1149*C146)/1682*1000 |                 |   |   |                          | =2*B149A1151 |
| 150 | O   | =B4        |                  | =(1150*C146)/1682*1000 |                 |   |   |                          | =6*B150A1151 |
| 151 | Total g/mole                                |            |                  |                        | =SUM(D147:D150) |   |   | =B147+B148+2*B149+6*B150 |              |
| 152 |   |            |                  |                        |                 |   |   |                          |              |
| 153 | ZnO   |            | =0.08*1682/1000  |                        |                 |   |   |                          |              |
| 154 | Zn  | 65.39      |                  | =(1154*C153)/1682*1000 |                 |   |   |                          | =B154A1156   |
| 155 | O   | =B4        |                  | =(1155*C153)/1682*1000 |                 |   |   |                          | =B155A1156   |
| 156 | Total g/mole                                |            |                  |                        | =SUM(D153:D155) |   |   | =B154+B155               |              |
| 157 |   |            |                  |                        |                 |   |   |                          |              |

|     | A                | B                      | C                   | D             | E                                | F               | G               | H              | I                   |
|-----|------------------|------------------------|---------------------|---------------|----------------------------------|-----------------|-----------------|----------------|---------------------|
| 158 | Element/Compound | Atom Wt.               | Moles in Container  | Element Wt. % | Element Moles                    | Moles of Oxygen | Wt. % of Oxygen | g/mole         | Fraction of Element |
| 159 | Group            |                        |                     |               |                                  |                 |                 |                |                     |
| 160 |                  |                        |                     |               |                                  |                 |                 |                |                     |
| 161 | B2O3             |                        | =10.28*1682/100     |               | =2*C161/(K162*2+B165*3)*100/1682 | =E161*3/2       | =B165*F161      |                |                     |
| 162 | B                | =0.199*B185+0.801*B186 |                     |               |                                  |                 |                 |                | =2*B162/H166        |
| 163 | B-10 (see note)  | 10.012937              | =E163*B163*1682/100 | =(B163)*E163  | =E161*0.199                      | =E163*(3/2)     | =B165*F163      |                |                     |
| 164 | B-11 (see note)  | 11.0093053             | =E164*B164*1682/100 | =(B164)*E164  | =E161*0.801                      | =E164*(3/2)     | =B165*F164      |                |                     |
| 165 | O                | =B4                    |                     |               | =(1165*C161)/1682*100            |                 | =SUM(G163:G164) |                | =3*B165/H166        |
| 166 | Total g/mole     |                        |                     |               | =SUM(D163:D165)                  |                 |                 | =2*K162+3*B165 |                     |
| 167 |                  |                        |                     |               |                                  |                 |                 |                |                     |
| 168 | LiO              |                        | =3.16*1682/100      |               | =2*C168/(K169*2+B172)*100/1682   | =E168/2         | =F168*B172      |                |                     |
| 169 | Li               | =0.075*B194+0.925*B194 |                     |               |                                  |                 |                 |                | =2*B169/H173        |
| 170 | Li-6 (see note)  | 6.015122               | =E170*B170*1682/100 | =E170*B170    | =E168*0.075                      | =E170*(1/2)     | =B172*F170      |                |                     |
| 171 | Li-7 (see note)  | 7.0160039              | =E171*B171*1682/100 | =E171*B171    | =E168*0.925                      | =E171*(1/2)     | =B172*F171      |                |                     |
| 172 | O                | =B4                    |                     |               | =(1172*C168)/1682*100            |                 | =SUM(G170:G171) |                | =B172/H173          |
| 173 | Total g/mole     |                        |                     |               | =SUM(D170:D172)                  |                 |                 | =2*B169+B172   |                     |
| 174 |                  |                        |                     |               |                                  |                 |                 |                |                     |
| 175 | Ag               |                        |                     | 0.05          |                                  |                 |                 |                |                     |
| 176 | Other            |                        |                     | 0.58          |                                  |                 |                 |                |                     |
| 177 |                  |                        |                     |               |                                  |                 |                 |                |                     |
| 178 |                  |                        |                     |               |                                  |                 |                 |                |                     |

Note: The value of 0.199 in the 5th column is the atom percent abundance for B-10 which comes from the Chart of Nuclides (Ref. 2 in the Ref. Section of the main report). The same is true for the values of 0.801 (B-11), 0.075 (Li-6) and 0.925 (Li-7).

|     | A             | B | C   | D                 |
|-----|---------------|---|---|-------------------|
| 171 | SUMMARY       |   |   |                   |
| 172 |               |   |   |                   |
| 173 | Element       |   | Wt. %, Not Normalized   | Wt. %, Normalized |
| 174 |               |   |   |                   |
| 175 | O             |   | =G10+G19+G21+G22+G28+D36+D41+D47+D52+D58+D63+D68+D73+D78+D83+D88+D93+D98+D104+D119+D129+D134+D139+D146+D151+D159+D165 | =C175/CS196*100   |
| 176 | U-234         |   | =D5   | =C176/CS196*100   |
| 177 | U-235         |   | =D6   | =C177/CS196*100   |
| 178 | U-238         |   | =D7   | =C178/CS196*100   |
| 179 | U-238         |   | =D8   | =C179/CS196*100   |
| 180 | Pu-238        |   | =D13  | =C180/CS196*100   |
| 181 | Pu-239        |   | =D14  | =C181/CS196*100   |
| 182 | Pu-240        |   | =D15  | =C182/CS196*100   |
| 183 | Pu-241        |   | =D16  | =C183/CS196*100   |
| 184 | Pu-242        |   | =D17  | =C184/CS196*100   |
| 185 | Ca-133        |   | =D28  | =C185/CS196*100   |
| 186 | Ca-135        |   | =D21  | =C186/CS196*100   |
| 187 | Ba-137        |   | =D30+D39  | =C187/CS196*100   |
| 188 | Al            |   | =D34+D144   | =C188/CS196*100   |
| 189 | S             |   | =D40+D57+D103+D124  | =C189/CS196*100   |
| 190 | Ca            |   | =D45+D51+D56  | =C190/CS196*100   |
| 191 | P             |   | =D48  | =C191/CS196*100   |
| 192 | Cr            |   | =D62  | =C192/CS196*100   |
| 193 | Ag            |   | 0.05  | =C193/CS196*100   |
| 194 |               |   |   |                   |
| 195 | Sub Col Total |   | =SUM(C175:C193)   | =SUM(D175:D193)   |
| 196 | Total         |   | =C195+F195  | =D195+G195        |
| 197 | Other         |   | 0.58  |                   |
| 198 | Check Total   |   | =C195+F195+C197-SUM(C180:C184)-G19+H11-D9-G9  |                   |
| 199 |               |   | From elements   |                   |
| 200 |               |   |   |                   |

|     | E       | F                        | G                 | H  |
|-----|---------|--------------------------|-------------------|--|
| 171 |         |                          |                   |  |
| 172 |         |                          |                   |  |
| 173 | Element | Wt. %, Not Normalized    | Wt. %, Normalized |  |
| 174 |         |                          |                   |  |
| 175 | Ni      | =D118                    | =F175/CS198*100   |  |
| 176 | Pb      | =D123                    | =F178/CS198*100   |  |
| 177 | Si      | =D128+D145               | =F177/CS198*100   |  |
| 178 | Th      | =D133                    | =F178/CS198*100   |  |
| 179 | Ti      | =D138                    | =F179/CS198*100   |  |
| 180 | Zn      | =D150                    | =F180/CS198*100   |  |
| 181 | B-10    | =D158                    | =F181/CS198*100   |  |
| 182 | B-11    | =D157                    | =F182/CS198*100   |  |
| 183 | Li-6    | =D183                    | =F183/CS198*100   |  |
| 184 | Li-7    | =D184                    | =F184/CS198*100   |  |
| 185 | F       | =D114                    | =F185/CS198*100   |  |
| 186 | Cu      | =D67                     | =F188/CS198*100   |  |
| 187 | Fe      | =D72+D77                 | =F187/CS198*100   |  |
| 188 | K       | =D82                     | =F188/CS198*100   |  |
| 189 | Mg      | =D87                     | =F189/CS198*100   |  |
| 190 | Mn      | =D92                     | =F190/CS198*100   |  |
| 191 | Na      | =D87+D102+D108+D113+D143 | =F191/CS198*100   |  |
| 192 | Cl      | =D109                    | =F192/CS198*100   |  |
| 193 |         |                          |                   |  |
| 194 |         |                          |                   |  |
| 195 |         | =SUM(F175:F192)          | =SUM(G175:G192)   |  |
| 196 |         |                          |                   |  |
| 197 |         |                          |                   |  |
| 198 |         |                          |                   | =H11+H24+SUM(E37:E152)+E159+E166+D168+D169 |
| 199 |         |                          |                   | From compounds                             |
| 200 |         |                          |                   |  |