*Calculation of the $\text{LiF-CeF}_3\text{-BeF}_2$ and
 $\text{LiF-PuF}_3\text{-BeF}_2$ Ternary Phase Diagrams*

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CALCULATION OF THE LiF-CeF₃-BeF₂ AND LiF-PuF₃-BeF₂ TERNARY PHASE DIAGRAMS

by

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ABSTRACT

The LiF-CeF₃-BeF₂ and LiF-PuF₃-BeF₂ ternary phase diagrams were calculated from the optimized binary diagrams using computer programs developed by Lukas and coworkers.¹ The approximate overall diagrams were calculated without the use of ternary interaction terms, but inclusion of ternary terms was necessary to reproduce the experimental data for the solubilities of CeF₃ and PuF₃ which are considerably less soluble in the LiF-BeF₂ liquid than is predicted by calculation without ternary interaction terms.

1. THE LiF-CeF₃-BeF₂ TERNARY SYSTEM

Part 1 describes calculation of the LiF-CeF₃-BeF₂ ternary phase diagram. Computer programs developed by Lukas¹ were used. The general procedure was to derive polynomial expressions for the liquid phases of the three binaries by using the least-square fitting program BINGSS. Only one compound is involved, Li₂BeF₄, and the free energy of formation is available from the JANAF tables.² The compound is assumed to be stoichiometric, as are the three components.

The free energies of melting of the components were used in the simplest form, $A + BT$, where A is the heat of fusion and B is minus the entropy of fusion, and T is the temperature in Kelvins. Data for the components are given in Table 1.

Table 1. Melting Parameters for the Components

Component	Temperature (K)	Heat of Fusion J/mol	Entropy of Fusion J/mol-deg
LiF	1121	26778.	23.888
BeF ₂	825	4749.	5.756
CeF ₃	1710	56484.	33.031

The BINFKT program allows calculation of the binary phase boundaries once the necessary excess free energy coefficients have been determined.

When the thermodynamics of the binary systems have been established from the fitting procedure and/or literature data, they may be combined to calculate the ternary

phase relations with the TERFKT program. Either no ternary interactions can be assumed or ternary interactions may be introduced. If ternary interaction parameters are needed, they can be determined by fitting ternary phase diagram data using the TERGSS program.

In the programs, the excess free energy of mixing of the liquid phase is described by the Redlich-Kister³ polynomial. To interpolate free energies from the binary systems into the ternary composition triangle, the Muggianu⁴ formula was used.

1.1. The LiF-BeF₂ Binary System

The system has one compound, Li₂BeF₄, which melts congruently at about 730 K. There is a eutectic between the compound and LiF very close to the compound and also at about 730 K. The eutectic between the compound and BeF₂ is at about 634 K and 0.53 BeF₂.

1.1.1. Experimental Data. The measured liquidus data of Romberger et al.⁵ were used for the composition range from 0 to about 50 percent BeF₂, and those of Thoma et al.⁶ from 50 to 100 percent BeF₂. The free energy of formation of the compound Li₂BeF₄ was taken from the JANAF tables,² which reference a report by P. Gross, who measured a heat of formation of -5.05 ± 0.06 Kcal/mol from LiF(c) and BeF₂(glass). The correction for the conversion of BeF₂ glass to crystal (1.17 Kcal/mol) was used. The JANAF estimate of a zero entropy of formation was used. The free energy of formation of the compound from LiF(c) and BeF₂(c) was thus used as -16234. J/mol. at all temperatures.

1.1.2. Fitted Parameters. It was difficult to obtain a fit with the BINGSS program. Although the data of Romberger et al. are apparently more accurate, it was necessary to assign an uncertainty of ± 1 degree in order to obtain a suitable weighting compared to the Thoma data which were assigned ± 3 degrees uncertainty. The liquidus fit close to pure BeF₂ is still somewhat unsatisfactory. Figure 1 shows the data and the fitted boundaries. The eutectic and congruent melting for Li₂BeF₄ are shown in a magnified plot in Figure 2.

The system contains four phases: liquid, LiF, BeF₂, and Li₂BeF₄. The latter three were assumed to be stoichiometric. Table 2 gives the Redlich-Kister coefficients for the liquid derived from the fitting procedure.

Table 2. Redlich-Kister Coefficients, LiF-BeF₂ Liquid Phase, Joule Units

$G_{xs} = X(1)X(2) \sum_i (a_i + b_i T) (X(1) - X(2))^i$		
i	a_i	b_i
0	-20781.04	-9.755
1	-81506.992	75.564
2	20179.20	-15.988
3	-1239.87	0.0

Table 3 shows the comparison between the calculated and measured features of the LiF-BeF₂ system.

Table 3. Comparison between Measured and Calculated Features of the LiF-BeF₂ System

	$X(\text{BeF}_2)$		$T(K)$	
	calc	meas	calc	meas
Eutectic	0.329	0.328	729.6	732.1
Congruent Melting Point	0.333	0.333	729.6	732.3
Eutectic	0.518	0.531	634.4	636.7

1.2. The LiF-CeF₃ Binary System

The system is a simple eutectic at about 1028 K and 0.19 CeF₃.

1.2.1. Experimental Data. Phase diagram data are given by Barton et al.⁷

1.2.2. Fitted Parameters. Table 4 gives the Redlich-Kister coefficients derived from the fit. These give a eutectic temperature of 1028 K, compared to the observed 1029 K; and a composition of $X(\text{CeF}_3) = 0.182$, compared to the observed 0.190.

Table 4. Redlich-Kister Coefficients for the LiF-CeF₃ Liquid Phase

i	a_i	b_i
0	-11546.06	0.0
1	-1208.83	0.0

Figure 3 shows the phase diagram with observed data points and calculated boundaries.

1.3. The CeF₃-BeF₂ Binary System

The system is a simple eutectic, with the composition very close to pure BeF₂. The tendency of BeF₂ to exist as a glassy form makes experimental determination of melting difficult.

1.3.1. Experimental Data. The data of Barton et al.⁵ are scanty and somewhat scattered. They established the eutectic temperature at 540°C (813 K) by two DTA points. The eutectic composition was determined to be at $X(\text{BeF}_2) = 0.96 \pm 0.01$ by extrapolation of the liquidus boundary.

1.3.2. Fitted Parameters. Barton's liquidus points were ignored, and a fit was done with BINGSS using only the eutectic point at $T = 813$ K, $X(\text{BeF}_2) = 0.96$ as data. The fitted parameters gave 804 K, 0.98 for the calculated eutectic, using either one or two coefficients in the excess free energy expression. As it is likely that the measured temperature is more reliable than the composition, a closer fit to the temperature seemed desirable.

Using an ideal solution model for the liquid gave a eutectic temperature of 811 K with $X(\text{BeF}_2) = 0.988$. The ideal solution assumption was adopted and used to compute the phase diagram of Figure 4.

1.4. The LiF-CeF₃-BeF₂ Ternary System

This ternary system is characterized by the very small solubility of CeF₃ in the binary LiF-BeF₂ liquid. The ternary eutectics are very close to the LiF-BeF₂ side of the ternary composition triangle, and the major feature of the ternary diagram is the liquidus surface bounding the CeF₃-liquid region. The measured data are for the solubility of solid CeF₃ in the liquid and thus lie on the liquidus surface. Experimental data were obtained for temperatures of about 1000 K and below. There are at least two possible constructions above 1000 K. One is to assume that solubility increases with temperature so that at 1710, the melting point of CeF₃, complete solubility exists. Another is to assume that the small solubility of solid CeF₃ implies small solubility of liquid CeF₃, so that two immiscible liquids exist above 1710 K. The available data do not permit a choice, and the matter is unresolved until experimental data are obtained. Barton et al. assumed that complete miscibility existed at 1710 K, which is a reasonable choice.

1.4.1. Experimental Data. The ternary phase diagram is given by Barton et al.⁷ who derived it from solubility data of Ward et al.,⁸ plus DTA data. The liquidus boundary isotherms shown were evidently estimated, as the cited solubility data do not extend above about 1000 K, and only a single acceptable liquidus point at 1196 K is given by Barton et al.

1.4.2. DTA Data. DTA data were obtained for four ternary compositions (Barton et al.'s Table 3). The present calculated boundaries are compared with the DTA observations in the table below. Only one liquidus point, 1196 K at 45.0 percent BeF₂, 10.0 percent CeF₃ is labeled as "good data." The solidus data appear to be reliable. Results from the present calculation are compared with the DTA data in Table 5. A number of apparently spurious thermal effects are listed in Reference 7.

1.4.3. Ternary Solubility Data. Ward⁸ measured the solubility of CeF₃ in several compositions of LiF-BeF₂. These data represent intersections of the liquidus surface with isopleth planes. For example, the data points giving the solubility vs. temperature of solid CeF₃ in a LiF-BeF₂ solvent containing 24.4 mole per cent BeF₂ lie in the liquidus surface on a join between the pure CeF₃ corner and 24.4 mole percent BeF₂ on the LiF-BeF₂ binary side of the triangle.

The data for each LiF-BeF₂ liquid fall fairly well on straight lines on a $\log X(\text{CeF}_3)$ vs. $1/T$ plot. If complete liquid miscibility exists, the upper ends of the solubility lines should be at 100 percent CeF₃ at 1710 K. If, on the other hand, liquid immiscibility exists, the lines will pass through some point at less than 100 percent CeF₃ at 1710 K. The lower ends should be where the appropriate join crosses the eutectic valley.

1.4.4. Calculated Results. For other salt systems, good agreement between the calculated ternary diagram and experiment has been achieved without having to use ternary interaction terms.^{9,10} That is, the ternary diagram is calculated by interpolation from

Table 5. Ternary DTA Data from Barton et al., and Calculated Ternary Boundaries

Composition (mole %)		Temperature			
BeF ₂	CeF ₃	observed (°C)	(K)	calc (K)	
50.5	3.0	356	629	634	solidus
32.3	5.0	461	734	730	solidus
		832	1105	1165	liquidus
30.6	10.0	935	1208	>1300	liquidus
		470			
		453	726	730	solidus
		403			
		373			
		356			
		337			
45.0	10.0	923	1196	>1300	liquidus
		864			
		740			
		353	626	634	solidus

the three binaries. Several interpolation formulas are available. The Muggianu⁴ formula gives equal weight to all three components, while the Toop¹¹ formula is asymmetric, weighting one component differently than the other two.

The important feature of the present system is the small solubility of CeF₃ in the LiF-BeF₂ liquid, and comparison between the calculated and experimental solubilities is the main basis for evaluation of the calculated ternary diagram.

1.4.4.1. Calculation with No Ternary Interactions. Calculations with no ternary interaction terms gave small solubilities of solid CeF₃ in the liquid, in qualitative agreement with the data, but the calculated numbers were about a factor of three larger than the data when the symmetric Muggianu formula was used. Use of the Toop formula with CeF₃ differently weighted than the other two components gave slightly higher solubility values. The calculated temperatures of two ternary eutectics and the saddle point were almost identical to those calculated using ternary interactions (Table 7), but the CeF₃ concentrations were higher, in accord with the higher solubilities.

The liquidus surface calculated with no ternary interaction terms up to the melting point of CeF₃ (1710 K) gave isotherms roughly in agreement with those postulated by Barton. While this liquidus seems reasonable in both cases, Barton's and the present one, it is speculative and unsupported by evidence. The solubility points lie in this surface, and extrapolation on a log $X(\text{CeF}_3)$ vs. $1/T$ plot should pass through $X(\text{CeF}_3) = 1$ at $T = 1710$ if this interpretation is correct. Extrapolation of the experimental data is not unequivocal; however, the result is adopted as the probable approximate construction for the ternary diagram.

1.4.4.2. Calculation with Ternary Interactions. Ternary terms were determined by fitting the solubility data with TERGSS. The program offers ternary interaction polynomials with one, three, or six constants. The constants may have temperature dependence with up to six coefficients if desired. The simplest is

$$G_{xs} = X(1)X(2)X(3)K$$

where the constant K has temperature dependence of the form: $K = a + bT$.

This is the one-constant polynomial. The temperature dependence provides two coefficients, thus to fit the data there are two free parameters: a and b .

A more complex ternary interaction is of the form

$$G_{xs} = X(1)X(2)X(3) (K_1X(1) + K_2X(2) + K_3X(3))$$

where the K s can have temperature dependence so as to give six or more free parameters. A more complicated polynomial with six constants and twelve or more possible parameters is also provided in the program.

The excess free energies described by the polynomials add to the ternary excess free energy calculated by interpolation between the three binaries.

Satisfactory fits to the solubility data were obtained using three constants with no temperature dependence in the second expression above. Some fits are shown in Figures 5 and 6. The ternary interaction parameters are given in Table 6.

**Table 6. Ternary Interaction Parameters,
LiF-CeF₃-BeF₂ System**

$$G_{xs} = X(1)X(2)X(3) (K_1X(1) + K_2X(2) + K_3X(3))$$

$$K_1 = 64918.1 \quad K_2 = 375280.7 \quad K_3 = -16295.2$$

Extrapolation outside the range of the data using this polynomial should not be done. In general, polynomials fitted to data give unreliable results when extrapolated outside the range of the data they fit. In the present case, a major problem is that the liquidus surface to be fitted is close to the LiF-BeF₂ binary side of the diagram at the lower temperatures. Any ternary interaction polynomial must go to zero at the binary sides of the ternary triangle, and thus the expressions necessarily provide small values for the excess free energy close to the sides. Attempts to fit the solubility data may be successful but give large excess free energies in the center of the diagram where there are no data to influence the fit. Thus extrapolation outside the range of the data using the fitted parameters is unreliable, and prediction of the liquidus above 1000 K is not possible.

The calculated ternary eutectics and saddle point are compared with Barton's deductions in Table 7.

Table 7. Features of the LiF-CeF₃-BeF₂ Ternary System

	$X(\text{CeF}_3)$		$X(\text{BeF}_2)$		$T(K)$	
	calc	Ref. 7	calc	Ref. 7	calc	Ref. 7
Eutectic	0.0009	0.0012	0.328	0.327	729.9	731.6
Saddle Point	0.0010	0.0012	0.333	0.333	730.0	731.8
Eutectic	0.0004	0.0009	0.520	0.531	634.4	636.2

1.5. Discussion

It was hoped that calculation of the ternary diagram could provide a means to fill in the parts of the diagram undefined by experimental data. An approximate diagram can be produced by interpolating from the binaries with no ternary interaction terms, but this result does not reproduce very well the solubility data which lie in a very limited part of the diagram. In order to make the calculated results fit the data it was necessary to use a ternary interaction expression with three free parameters. This gave reasonably satisfactory fits to the data but precluded the possibility of extrapolation either to temperatures higher than the 1000 K upper limit of the data or to compositions outside the data range.

This leaves the ternary diagram above 1000 K speculative. Figure 7 is presented as a likely possibility; however, the CeF_3 solubilities below 1000 K, which are calculated using the assumption of no ternary interactions, which produced Figure 7, are higher than those observed. There is a possibility that the small solubility of solid CeF_3 in the LiF-BeF_2 liquid may lead to small solubility of the liquid, giving two immiscible liquids at higher temperatures. Experimental data are needed to resolve the question.

Without ternary interactions, the observed small solubilities are qualitatively reproduced by the calculation and show that the interactions deduced by fitting the data do reflect the real situation, although not as well as they have done for other systems. The LiF-BeF_2 system shows a strong attraction between the components, as shown by large negative excess free energy. The other two binaries, LiF-CeF_3 and $\text{BeF}_2\text{-CeF}_3$ are close to ideal, with little if any attraction between components. Thus, in the LiF-BeF_2 liquid, CeF_3 is even less strongly bonded than in the binaries, and the solubility is very small, becoming smallest at the LiF-BeF_2 composition for which the free energy of formation of the LiF-BeF_2 liquid is most negative.

1.6. Appendix A. Data Interpolation for the $\text{LiF-CeF}_3\text{-BeF}_2$ Ternary System

In order to facilitate interpolation of the experimental data so as to better compare with the calculated results in Figure 5, least square fits were done of the form:

$$\log S = a_0 + a_1(1000/T)$$

where $\log S$ is the common logarithm of the concentration of CeF_3 in mole percent and T is temperature. The coefficients for each of the LiF-BeF_2 liquids measured by Ward⁸ are listed below:

Percent BeF_2	No. of points	a_0	a_1	Temperature Range (K)
28.5	4	3.8885	-3.5126	783-1006
32.5	4	3.1793	-2.9758	786-1013
34.5	8	3.7450	-3.4950	747-1007
37.3	4	3.4873	-3.3046	740-993
40.7	4	3.4291	-3.2402	749-977
43.3	4	3.2313	-3.0254	698-996
46.2	5	3.0055	-2.7794	685-990
48.4	4	2.8902	-2.6406	680-999

1.7. Appendix B. Calculation Comparison

The results of solubility calculations in the 65.5 LiF-34.5 BeF₂ liquid are shown in Table A2. Results from the Muggianu and Toop interpolation formulas are shown for the case with no ternary interactions. As might be expected, the use of three coefficients gives a better fit than two or none. The two-coefficient expression is the first one given in Sec. 5.2.2 with a and b as free parameters. The three-coefficient expression uses K_1 , K_2 , and K_3 as given in Table 6.

Table A2. Comparison of Solubility Calculations. Percent CeF ₃ in LiF-BeF ₂ Liquid Containing 34.5 Percent BeF ₂				
Temp (K)	Exptl. Data	Calculated no coeff	2 coeff	3 coeff
800	0.24	0.96 M 1.18 T	0.31	0.26
900	0.73	2.74 M 3.08 T	0.87	0.79
1000	1.78	6.24 M 6.56 T	2.01	1.82
Note: M = Muggianu interpolation, T = Toop interpolation				

2. THE LiF-PuF₃-BeF₂ TERNARY SYSTEM

Calculation of the LiF-PuF₃-BeF₂ ternary phase diagram is described. The three binary phase diagrams were first fitted, then combined to calculate the ternary diagram. PuF₃ is very similar to CeF₃, thus the present work is a follow-on to the LiF-CeF₃-BeF₂ phase diagram calculation presented in Part 1.

Table 8 gives the melting parameters for the component fluorides.

Table 8. Melting Parameters for the Components			
Component	Temperature (K)	Heat of Fusion J/mol	Entropy of Fusion J/mol-deg
LiF	1121	26778	23.888
PuF ₃	1698	33054	19.466
BeF ₂	825	4749	5.756

2.1. The LiF-BeF₂ Binary System

This phase diagram is described in Part 1.

2.2. The LiF-PuF₃ Binary System

Phase diagram data are given by Barton and Strehlow.¹² They show a eutectic at a temperature of 1016 K and a composition of $X(\text{PuF}_3) = 0.195$. Fitting with the BINGSS program gave a eutectic at 1017 K with $X(\text{PuF}_3) = 0.211$. The Redlich-Kister coefficients derived are in Table 9.

The calculated phase boundaries are compared with the experimental data in Figure 8.

Table 9. Redlich-Kister Coefficients for LiF-PuF₃ Liquid, Joule Units

i	a_i	b_i
0	642.87	0.0
1	-5393.02	0.0

2.3. The PuF₃-BeF₂ Binary System

No experimental measurements were available for this system. The CeF₃-BeF₂ system described in Part 1 was fitted using the assumption that the liquid was an ideal solution. As PuF₃ and CeF₃ are very similar, the same assumption was used again. The radius of the Ce⁺³ ion is 1.00 Å, that for Pu⁺³ is 1.01 Å. The melting point of CeF₃ is 1710 K, that of PuF₃ is 1698 K. There is some difference in the heat of fusion: 56484 J/mol for CeF₃, vs. 33054 for PuF₃.

The assumption that the liquid was ideal gave a simple eutectic phase diagram with a eutectic point at 761 K and 0.94 BeF₂ as shown in Figure 9.

2.4. The LiF-PuF₃-BeF₂ Ternary System

2.4.1. Experimental Data. Barton¹³ measured the solubility of solid PuF₃ in several compositions of LiF-BeF₂ liquid at temperatures between 735 K and 935 K. The results are similar to the corresponding CeF₃ data, and very low solubilities were observed. The data fall reasonably well on straight lines in log mole fraction-reciprocal temperature coordinates. Extrapolations of the lines appear to pass through 100 percent PuF₃ at 1698, the melting point, suggesting that the liquidus surface bounding the solid PuF₃-liquid phase region passes through the PuF₃ melting point, and that there is no liquid immiscibility.

2.4.2. Calculations. As with the LiF-CeF₃-BeF₂ system, calculation of the ternary diagram without ternary interactions gave solubilities that were small but considerably higher than those observed. The solubility data were fitted using TERGSS with the three constant expression for ternary interactions; the fitted constants are in Table 10, and the calculated solubilities are compared with those observed in Figures 10 and 11. In order to be able to interpolate between the measured data points, the data were fitted with straight lines in log S vs. $1/T$ coordinates as described in the Appendix.

**Table 10. Ternary Interaction Parameters,
LiF-PuF₃-BeF₂ System**

$$G_{xs} = X(1)X(2)X(3)(K_1X(1) + K_2X(2) + K_3X(3))$$

$$K_1 = 91240.8 \quad K_2 = -235294.7 \quad K_3 = 37989.0$$

The ternary eutectics and saddle point calculated using the ternary interactions are in Table 11. The eutectic at 729.9 K has liquid, LiF, Li₂BeF₄, and PuF₃ coexisting; at the saddle point Li₂BeF₄, PuF₃ and liquid coexist; and at the 634.4 K eutectic, Li₂BeF₄, BeF₂, PuF₃ and liquid coexist.

**Table 11. Features of the LiF-PuF₃-BeF₂
Ternary System**

	X(PuF ₃)	X(BeF ₂)	T(K)
Eutectic	0.00092	0.3281	729.9
Saddle Point	0.00090	0.3330	730.0
Eutectic	0.00038	0.5204	634.4

As before, use of a ternary interaction polynomial fitted to the data in a limited part of the phase diagram precludes extrapolation to ranges outside the data fitted. In the present case, the maximum temperature at which data were obtained was 935 K. The liquidus surface bounding the PuF₃-liquid region and representing the solubility of PuF₃(s) in the LiF-BeF₂ liquid at temperatures above 935 K is undefined by data and cannot be predicted by the calculation using the fitted ternary interaction parameters. However, it appears likely that liquidus isotherms calculated at temperatures above 935 K without ternary interaction terms will be a fair approximation, and the ternary diagram so calculated is shown in Figure 12. Although this is presented as a likely construction, experimental results are needed to confirm it. The possibility exists that small solubility of solid PuF₃ indicates small solubility of liquid PuF₃, and thus immiscible liquids may occur at high temperatures.

2.5. Discussion

This system, like the LiF-CeF₃-BeF₂ system is not amenable to prediction of the ternary phase diagram from the three binaries alone. The combination of a strongly bonded binary system, LiF-BeF₂, and two systems with little or no attractive force between the components, LiF-PuF₃ and BeF₂-PuF₃ produces a ternary system which is not easily predictable quantitatively. A further difficulty is that ternary data are available only in a very limited region of the diagram. In order to fit the ternary data it was necessary to use a complicated polynomial with coefficients determined from the data. Such polynomials cannot be extrapolated beyond the data range they fit; attempts to do so produce obviously incorrect results.

It is assumed that the ternary phase diagram calculated with no ternary interactions is a reasonable approximation to the actual diagram. However, there is a possibility that liquid immiscibility may exist. Experimental measurements are needed to verify the assumption.

2.6. Appendix C. Data Interpolation for the LiF-PuF₃-BeF₂ Ternary System

The data points were scaled from the plots in Reference 13. Least square fits of these data were done to enable interpolation to better compare with the calculated solubilities. The function was:

$$\log S = a_0 + a_1(1000/T)$$

where $\log S$ is the common logarithm of the solubility in mole percent and T is the temperature in kelvins. Table A3 shows the coefficients derived.

Table A3. Least Square Fits of the Solubility of PuF₃ in LiF-BeF₂ Liquid.

Percent BeF ₂	No. of points	a_0	a_1	Temperature Range (K)
28.7	3	3.2521	-2.8859	820-922
31.9	4	3.3037	-3.1387	795-927
37.0	4	3.0187	-2.9539	808-935
43.7	5	4.1165	-3.8588	824-932
48.3	3	2.8704	-2.6958	735-927

Fig. 1. The LiF-BeF₂ Binary Phase Diagram. The lines are plotted from the calculations. Data points are from Romberger et al.³ and Thoma et al.⁴

Fig. 2. Magnified portion of the LiF-BeF₂ Diagram to show the calculated eutectic and congruent melting of Li₂BeF₄.

Fig. 3. The LiF-CeF₃ Binary Phase Diagram. The lines are plotted from the calculations. Data points are from Barton et al.⁵

Fig. 4. The $\text{CeF}_3\text{-BeF}_2$ Binary Phase Diagram. The lines are plotted from the calculations. Data points are from Barton et al.⁵

Fig. 5. Isothermal plots showing the solubility of CeF_3 in LiF-BeF_2 liquid. The lines are plotted from the calculations. The points are obtained by interpolation of the data using least square fits. See appendix.

Fig. 6. Temperature dependence of CeF_3 solubility in selected $\text{LiF}-\text{BeF}_2$ liquids. The lines are plotted from the calculations. Data points are from Ward.⁸

Fig. 7. The $\text{LiF}-\text{CeF}_3-\text{BeF}_2$ ternary diagram. Isotherm contours in the liquidus surface are shown, as well as valleys.

Fig. 8. The LiF-PuF₃ Binary Phase Diagram. The symbols represent experimental data points, the lines are calculated.

Fig. 9. The PuF_3 - BeF_2 Binary Phase Diagram. No data are available, the boundaries are calculated assuming the liquid to be an ideal solution.

Fig. 10. Isothermal plots comparing calculated and observed solubilities of PuF₃ in various LiF-BeF₂ liquids.

Fig. 11. Comparison of observed vs. calculated solubilities of PuF_3 in various LiF-BeF_2 liquids.

Fig. 12. The LiF - PuF_3 - BeF_2 ternary diagram. Proposed isotherm contours and liquidus valleys are shown.

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