# Molten Salts: Volume 4, Part I, Fluorides and Mixtures

## Electrical Conductance, Density, Viscosity, and Surface Tension Data

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Data on the electrical conductance, density, viscosity, and surface tension of fluoride mixtures have been systematically collected and evaluated. Results are given for 44 binary mixtures over a range of compositions and temperatures. Values of the above properties for the single salts have been updated in accord with previously advanced recommendations.

Key words: Data compilation; density; electrical conductance; molten salt mixtures; fluorides; standard reference data; surface tension; viscosity.

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## 1. Introduction

This series of compilations includes thermodynamic, transport, and physical properties of selected inorganic salts in the molten state. The early sections covered single-salt melts, i.e., one-component systems in the classical phase-rule sense. Evaluated data on electrical conductance, viscosity, and density of single-salt melts were published in *Molten Salts, Vol. 1* (NSRDS–NBS–15 [1],[1] and surface tension was covered in Vol. 2 (NSRDS–NBS–28) [2]. Following the completion of that work, evaluation of data on the same four properties of binary molten salt mixtures was undertaken. The following classification was adopted from the many possible binary mixtures of inorganic compounds:

- nitrates-nitrates, nitrites-nitrites, and nitrates-nitrites
- halides-halides
  fluorides-fluorides; chlorides-chlorides; bromides-bromides and iodides-iodides; mixed halides
- additional binary systems
  carbonates-carbonates, sulfates-sulfates, . . . and mixed systems.

The recommendations for the nitrates-nitrates, nitrites-nitrites, and nitrates-nitrites, together with a Vol. 1 [1] update for the relevant single-salts melt data were reported in *Molten Salts, Vol. 3* [3]. The recommendations for the halides-halides, and for the additional binary systems are being prepared as Vols. 4 and 5 of this series. The results for the binary mixtures of halides, i.e., *Molten Salts, Vol. 4*, will be reported in four parts: Part 1, fluorides-fluorides; Part 2, chlorides-chlorides; Part 3, bromides-bromides and iodides-iodides; and Part 4, mixed halide systems. An

[1] Numbers in brackets refer to literature references in section 7.

update of the recommendations of Vol. 1 [1] for the relevant single-salts melt data is given in each of these parts. The results for some 44 fluoride-fluoride mixtures, and the single-salts melts update are reported herewith as Vol. 4, Part 1. The study includes published results up to approximately 31 December, 1972.

In this volume the discussion has been limited to essential observations concerning experimental procedures and melt preparation and purification. A tabular style is used wherever possible to display the important published results, recommended values, percent departures, and temperature and composition ranges.

As in Vol. 3 the limits imposed by the statistical analysis of the data required the comparisons for conductance and viscosity data to be made at the same compositions as in the original experimental studies; the recommendations are advanced accordingly, but at rounded temperatures. For density and surface tension, it was possible in some cases to report the properties at rounded values of temperature and composition.

Tables of numerical values follow immediately after the tabular presentations of the data sources and other comments. A temperature-liquidus phase diagram has been included wherever possible, to delineate to the lower limits of the liquidus ranges for the binary mixtures; however it should be understood that phase diagrams in this work are present for illustrative purposes and are not advanced as critically evaluated recommendations.

The fluoride mixtures are arranged in alphabetical order by cations according to chemical symbol. A system index is also given in the contents.

## 2. Symbols and Units

The symbols and units[2] for the four physical properties in this compilation are:

$\kappa$ = specific conductance ($ohm^{-1}cm^{-1}$)
$\rho$ = density ($gcm^{-3}$)
$\eta$ = viscosity (cp)
$\gamma$ = surface tension (dyn $cm^{-1}$)[3]

In addition:

$E$ = activation energy (cal $mol^{-1}$)
$\Lambda$ = equivalent conductance ($ohm^{-1}$ $cm^2$ $equiv^{-1}$)
$C$ = concentration (mol %)
$R$ = gas constant = 1.9817 cal $mol^{-1}deg^{-1}$
$T$ = temperature in kelvin, defined on the thermodynamic scale by assigning 273.16 K to the triple point of water (freezing point, 273.15 K = 0 °C).

[2] For conversion to SI units:

1 $ohm^{-1}$ cm = $1 \times 10^{2}\Omega^{-1}m^{-1}$
1 $gcm^{-3} = 1 \times 10^{3}$ Kg $m^{-3}$
1 cp = $1 \times 10^{-3}$ N s $m^{-2}$
1 dyn $cm^{-1} = 1 \times 10^{-3}$ N $m^{-1}$
1 cal $mol^{-1} = 4.184$ J $mol^{-1}$

[3] When $\gamma$ is treated as a free energy per unit area, it is given the unit, erg $cm^{-2}$; this is dimensionally identical to dyn $cm^{-1}$.

## 3. Experimental Methods

Authoritative reviews discussing experimental methods for studying transport properties of molten salts have been given elsewhere [3, 11, 21, 38, 53, 99]. Robbins [101] has reviewed the electrical conductance measurements on molten fluorides, with respect to the effects of cell design, materials for fabrication, and bridge methods for precise resistance measurements. The following section will highlight and reference certain experimental aspects that are generally restricted to the study of fluoride melts. Further information for specific fluoride systems has been included in the discussion sections (5.3 and 6.1) for single and binary melts, respectively.

### 3.1. Techniques

In the measurement of the electrical conductance of fluoride melts suitable materials for the construction of cells are extremely difficult to find [63] since most substances, if not rapidly attacked, are sufficiently porous to allow liquid penetration. Conductivity measurements have been made in cells constructed primarily from platinum [46, 45, 111], but boron nitride in graphite [24, 87, 119], single crystal beryllium oxide [54] and magnesium oxide [23, 34, 39] have also been found useful. Silica glass has been used for capillary cells [22, 30] but in general has not been suitable due to fluoride attack at high temperatures [45]. Electrodes of platinum [45, 46], inconel [120], molybdenum [87], and molten aluminum [39, 96] have been used. The low cell constants normally obtained using these materials in conjunction with the high conductivity of molten fluorides has necessitated the use of accurate bridge methods for precise resistance measurements and these have recently received attention by Robbins [101]. Additional comments regarding the measurements of electrical conductance for specific fluoride systems have been included under the discussion sections (5.3 and 6.1).

Viscosity measurements on fluoride melts have been made using the capillary, oscillating sphere, oscillating hollow cylinder and rotational cylinder methods. Little reported experimental information was available regarding the capillary technique. Oscillating bodies were constructed of platinum [5, 107] and palladium [108]; and rotational cylinders of bronze [117] and inconel [18, 19, 33] have been used. Platinum [5], graphite [117], nickel [33] and inconel [18, 19] melt containers were used. Recently reported viscosity measurements by Grjotheim et al. [44] on several molten chloride melts using the oscillational technique showed large differences (10 to 50%) for NaCl and KCl when compared to results of earlier investigations using the same method. Experimental problems associated with the method included consideration of wire diameter for the suspension system and proper pretreatment of the torsion wire. The stability of the measured torsional constant appeared to be strongly dependent upon these factors. In light of these conflicting results,

data on viscosity of fluoride melts obtained using the oscillating technique should be viewed with caution until further information becomes available on the reliability of this method.

The Archimedean method for density determination has been found very reliable for molten salts and specifically for fluoride melts. Bobs of platinum [7, 25, 33, 75, 95, 107], molybdenum [87, 98], and Pt–10 percent Rh [49] have been most commonly used with melt containers of platinum, nickel and graphite. A nickel dilatometer has been successfully used [28, 30]. Calibration procedures and corrections for thermal expansion and melt condensation have been discussed under sections 5.3 and 6.1.

The maximum bubble pressure method has been most widely used for surface tension measurements on molten fluorides. Capillaries of Pt–10 percent Rh [20, 43] and molybdenum [67] have been used. Experimental methods have been reviewed by White [113] and Janz [64].

The preparation, handling and transfer procedures for molten fluorides during experimental measurements are discussed in sections, 5.3 and 6.1, for specific and binary fluoride melts, respectively.

### 3.2. Percent Application of Methods

Experimental methods for studying transport properties of molten fluoride melts were cited in section 3.1. The following summaries indicate the frequency of use of these techniques. The Percent Application is defined as the number of investigations employing a particular method relative to the total number of reported studies for that transport property.

Specific conductance

| Method | Percent Application |
|---|---|
| Classical ac | 97.8 |
| Potentiometric ac | 2.2 |

Density

| Method | Percent Application |
|---|---|
| Archimedean | 96.7 |
| Dilatometric | 3.3 |

Viscosity

| Method | Percent Application |
|---|---|
| Capillary | 30 |
| Oscillating sphere | 15 |
| Oscillating hollow cylinder | 2.5 |
| Rotational cyclinder | 52.5 |

Surface tension

| Method | Percent Application |
|---|---|
| Maximum bubble pressure | 92.9 |
| Wilhelmy slide plate | 7.1 |

### 3.3. Melt Preparation and Purification

Most fluorides are commercially available, either in technical or analytical pure grades, so that synthetic procedures are avoided. Emphasis is given here to details of salt purification.

The following procedures have been adopted: recrystallization, sublimation, vacuum distillation, fusion under HF gas and heating with $NH_4HF_2$ in the case of $UF_4$. The salts are mostly dehydrated in a Pt-crucible under vacuum at elevated temperatures with an inert atmosphere.

Mixtures are prepared by fusion of the required amounts of the pure components under an inert gas atmosphere. The composition and purity are usually checked using standard spectrochemical and gravimetric procedures.

Detailed procedures, including handling and transfer, for each salt or mixture are discussed in sections 5.1 and 6.1, respectively.

## 4. Treatment of Data

### 4.1. Statistical Analysis

The statistical analysis was performed on the computer facilities (IBM 360, PDP15 and G.E. Mark II Time-Sharing Unit) at Rensselaer Polytechnic Institute.

The density, specific conductance, viscosity, and surface tension values were recalculated by a one-dimensional analysis, using the method of least squares to establish equations indicating the variations of the physical quantities with temperature at the experimental composition. For density and surface tension results, where five or more experimental compositions and temperatures or temperature-dependent equations were reported, the values were recalculated by a two-dimensional analysis, using a stepwise multiple regression routine. In this way a physical property-temperature-composition matrix was developed. Tabulated values given in brackets are less reliable because of a statistically insufficient number of data points.

#### a. One-Dimensional Analysis

The criterion for choosing the equation of best fit in the one-dimensional analysis is the standard error of estimate computed from the residuals and defined by

$$s=\sqrt{\frac{\sum^{n}(\gamma_e-\gamma_c)^2}{n-q}}$$

where $\gamma_e$ = the experimental value at each temperature, $\gamma_c$ = the value calculated from the least squares equation at the same temperature as $\gamma_e$, $n$ = the number of experimental data points, and $q$ = the number of coefficients in the least squares equation (2 for linear, 3 for quadratic). The standard error of estimate is also expressed as a percentage.

#### b. Two-Dimensional Analysis

*Computer Programs Used*

Programs from the IBM Scientific Subroutine Package[4] were used with the IBM 360/50 computer facility at Rensselaer. The routines consist of STPRG, CORRE, LOC, and MSTR, the latter two being storage routines which have no effect on the accuracy of the results. In addition the subroutine STOUT is used to print the results of each regression step and the subroutine MATRIX is used for printing a matrix of the final equation.

*Statistical Procedures*

The abbreviated Doolittle method[5] was used to select the variables entering the regression and for calculation of coefficients. The independent variable included in each step of the analysis was selected by computing the reduction of sums of squares of each variable. The variable causing the largest reduction was added to the equation and deleted from the table of sums of squares. The coefficients, intercept and statistical parameters for the new equation were computed and printed. This procedure was repeated until the maximum proportion of sums of squares to the total reduced was less than a limit set by the programmer. The independent variables used in the initial selection were chosen from a generalized procedure, which generated 30 combinations of the input variables using powers, reciprocals, logarithmic and exponential quantities. It was found that the procedure consistently selected the equation $(T + C)^3$, so that the working program used nine independent variables. After the final equation has been produced, it is transferred to the MATRIX routine, which recalculates values at rounded compositions and temperatures, within specified boundary conditions. In the presentation of the matrix, due cognizance is taken of the experimental range of the investigation and of the phase relationships for the system so that values are always "interpolated" rather than "extrapolated". The final step in the procedure involves the residual analysis, where the deviations of the original values from those computed from the "best" equations are given.

*Statistical Parameters*

For each step in the regression analysis a summary of significant statistical parameters is given. First the sums of squares reduced ($S_i$), the proportions of $S_i/D$, where $D$ is defined below, given by $P$, the cumulative $S_i$ given by $S_{cum}$ and the cumulative proportion given by ($P_{cum}$) are listed. These quantities give an indication of the effect of each variable in the final equation. The programmers limit on $P$ was always in the range $0.0001 \leq P \leq 0.001$.

*Standard Error of Estimate*

The standard error in the estimated $y$ values adjusted for degrees of freedom is given by:

$$\text{s.e.} = \sqrt{\frac{D - S_{cum}}{n - q - 1}}$$

where

$$D = \sum_{j=1}^{n} (y_j - \bar{y})^2$$

$y_j$ = experimental values.
$\bar{y}$ = average of all experimental values.
$q$ = the number of independent variables in the equation.

The standard error of estimate is also expressed as a percentage. As a general guide about 68 percent of the results lie within the standard error of estimate, 95 percent within twice this value, and approximately 99 percent within three times the value.[6]

*F Value for Analysis of Variance*

This value is used to determine if a particular model is acceptable.[7] Tables of $F$ values indicate that values greater than 2.0 are acceptable for the routine used here. In all cases values of $F$ were greater than 500 and in most cases greater than 1000. The $F$ value is defined as:

$$F = \frac{S_{cum/q}}{(D - S_{cum})/(n - q - 1)}$$

where $S_{cum}$, $q$, $D$, and $n$ were defined earlier.

### 4.2. Percent Departure

The percent departure has been used to compare the results of different investigations with either previous [1, 2] or current recommendations and has been later considered when evaluating a study for possible recommendation.

The percent departure is defined by:

$$\text{Percent departure} = \frac{\text{"compared value"} - \text{"recommended value"}}{\text{"recommended value"}} \cdot 100$$

The "compared values" refer to the numerical data given in the discussed study and are compared to the "recom-

[4] System 360 Scientific Subroutine Package Programmers Manual; IBM 820-0205-3, 1969.

[5] C. A. Bennet and N. L. Franklin, Statistical Analysis in Chemistry and the Chemical Industry (John Wiley and Sons, 1954).

[6] T. D. Sterling and S. V. Pollack. Introduction to Statistical Data Processing (Prentice-Hall, 1968).

[7] H. Smith and N.R. Draper, Applied Regression Analysis (John Wiley and Sons, 1968).

mended values" given in NSRDS–NBS–15 [1] or NSRDS–NBS–28 [2], or the present work.

The experimental values, when available, were used as the "compared values", otherwise the "compared values" and the "recommended values" were calculated from statistically derived equations at common temperatures and compositions.

The percent departure is given in the discussion sections 5.3 for single salts and 6.1 for binary mixtures.

### 4.3. Value Judgments

The recommendations advanced in this work are based on three criteria: (a) type and quantity of experimental data available, (b) experimental method used, and (c) an error analysis of the reported results. The principles followed in selecting the most reliable data are, briefly, as follows:

(a) Studies reporting either numerical data, results derived from statistically generated equations or data in the form of temperature dependent equations were preferred over graphical results. Where investigations reporting numerical results and temperature dependent equations were of equal merit, normally the former was selected. For the case where two sets of results were reported for the same system, one graphical and the other numerical, the graphical results could be preferred if these were based on a more extensive composition and temperature range, when other criteria were of equal merit.

(b) The experimental aspects as discussed in section 3 were examined for each system when a recommendation has been advanced. Of primary importance was the cognizance of an investigator with respect to improvements and limitations on standard measuring techniques together with an examination of the errors leading to uncertainties in the measured transport properties. Attention was given to the preparation, purification, stability and analysis of single and mixed fluoride melts as discussed in section 3.3. The reliability of the measuring technique and melt preparation and purification procedures as determined from results on standard calibration materials was considered important in the ultimate value of the data reported.

(c) The statistical parameters and percent departures as discussed in section 4.1 and 4.2, respectively, were considered. For systems where investigations had similar quantity and quality of data, the results with superior statistical parameters were selected.

For some systems more than one reference has been advanced; this normally occurred when equally good data covered different composition and/or temperature ranges.

### 4.4. Discussion Tables

Transport properties of molten fluorides and their mixtures have been analyzed and summarized in tabular form with respect to: experimental methods employed, composition and temperature ranges studied, melt preparation and purification procedures and percent departures of numerical data from current or previous recommendations.

For each system the discussion table has been preceded by a brief introductory paragraph giving the recommended reference and experimental technique used, followed by three summary tables (where information exists), which contain respectively:

- the number of references critically re-examined
- the calculated percent departures

and

- the summary of cell materials and calibration methods.

Table A summarizes all investigations carried out for the relevant physical property with corresponding composition and temperature ranges. Data have been reported in numerical or equation form except where graphical results have been indicated.

Table B gives, when available, the minimum and maximum percent departures of the different investigations at comparable compositions and temperatures, in relation to previous recommendations [1, 2] or the present work. Experimental details such as cell materials and calibrations are presented, when available, in Table C for all investigations. Remarks concerning the accuracy, the reproducibility, and the form of numerical data are included. Additional comments may follow to highlight information of unusual importance (technique, experimental uncertainty, etc.) with respect to the particular property and system studied. Finally remarks on the salt preparation and purification are given.

The recommended investigation is always indicated by a bold-faced reference number in square brackets.

For certain systems more than one reference has been recommended where studies of comparable value have been reported covering different temperature and/or composition ranges.

A summary on melt preparation and purification is given for each system, when available.

### 4.5. Numerical Tables

The specific conductance, density, viscosity, and surface tension values were computed for each system for the experimental compositions at rounded temperatures using the corresponding "best" equation for the same temperature range for which the investigation was carried out. The temperature-dependent equations, the standard errors of estimate, the literature source and the form of the original data are given in each table. For density and surface tension the results were also recalculated using a two-dimensional statistical analysis in cases where sufficient data (more than five compositions and tempera-

tures) were given.

The matrices produced by the two-dimensional analysis are reported in tabular form at rounded temperatures and compositions; in addition the two-dimensional equation, maximum percent departure, standard error of estimate and literature reference are included in the table. Original values are given in cases where investigations reported only limited data or the one- or two-dimensional statistical analysis was unsuccessful. Numerical tables are presented only for the recommended studies and are given immediately after the discussions.

### 4.6. Phase Diagrams

Phase diagrams for each system are included in section 6.1 when available. It should be understood that the temperature-liquidus phase diagrams included in this work are not advanced as critically evaluated recommendations, but serve the useful purpose of reporting values for a eutectic composition. The liquidus curves were also used as guidelines for imposing the boundary conditions for generating the matrix, in order to avoid producing values in the solid phase. References for each phase diagram are given with the diagram.

### 4.7. General Summary Tables

Summary tables are given in section 5.4 (single salts) and section 6.2 (binary mixtures) to summarize specific information such as total number of investigations, recommended references, experimental techniques used, and literature references.

## 5. Single Salts

The sections 5.1 and 5.2 update the recommendations for single salt melts given in NSRDS–NBS–15 [1] and NSRDS–NBS–28 [2]. The discussions for each single salt recommendation and the numerical values together with the temperature dependent equations are given in section 5.3. References for single fluoride salts not included in NSRDS–NBS–15 [1] and NSRDS–NBS–28 [2] are listed in section 5.4.

### 5.1. New Recommendations

Single fluoride salts which do not appear in NSRDS–NBS–15 [1] and NSRDS–NBS–28 [2] are listed below. The discussions, numerical values and temperature-dependent equations for the new recommendations are given in section 5.3.

| Compound | Number of investigations | |
|---|---|---|
| | Density | Viscosity |
| $BeF_2$ | 3 | |
| KF | | 1 |
| LiF | | 2 |
| NaF | | 1 |
| RbF | 2 | |
| $UF_4$ | | 1 |

### 5.2 Revised Recommendations

The recommendations for single fluoride melts given in NSRDS–NBS–15 [1] have been updated relative to new investigations and in the case of NaF a revised recommendation is given in this volume. The recommendations given in NSRDS–NBS–28 [2] are still accepted.

The discussions, numerical values, and temperature-dependent equations for the revised recommendations are given in section 5.3.

| Compound | Number of investigations Density | NSRDS–NBS–15 [1] recommendation |
|---|---|---|
| NaF | 17 | p. 3 |

### 5.3. Discussions and Numerical Values

Single fluoride salts for which a new or revised recommendation is reported are discussed in this section with respect to experimental techniques, references, temperature ranges, percent departure values and melt preparation and purification. Numerical values are given for each property at rounded temperatures together with the temperature-dependent equations.

#### $BeF_2$

#### Density

The recommended values in table 2 are based on the work of Mackenzie and Cantor et al. (Archimedean method) [73] and [33], respectively.

TABLE 1 A. Investigations critically re-examined

| Ref. | Temp. Range ($T$) |
|---|---|
| 73 | 1073 |
| 33 | 1123 |
| 32 | 1073 |

Comment: The result reported in [33] is an upper limit of the actual $BeF_2$ density value. In reference [73] a surface tension of 200 dyn $cm^{-1}$ was assumed which yielded a corrected density value of $1.947 \pm 0.010$ $gcm^{-3}$ at 800 ° C.

### Melt Preparation and Purification

Mackenzie [73] used 99 percent pure $BeF_2$ contained in a Pt–20 percent Rh crucible and placed overnight in the apparatus under a stream of dry $N_2$. The apparatus was then evacuated to a pressure of about 10 mm Hg and the temperature was raised slowly to 200 °C to remove the water present. When the temperature was increased to 700 °C, dry $N_2$ was admitted. The melt was kept at 900 °C for 1 hr before measurements. In reference [33] $BeF_2$ was purified by vacuum distillation.

TABLE 2. $BeF_2$

| $T$ | $\rho$ ($gcm^{-3}$) |
|---|---|
| 1073.2 | $1.947 \pm 0.010$ [1] |
| 1123.2 | 1.96 [2] |

Density: [1] [73]
[2] [33]

## KF

### Viscosity

The recommended value in table 4 is based on the work of Sheiko (oscillating sphere method) [107].

TABLE 3 A. Investigations critically re-examined

| Ref. | Temp. Range ($T$) |
|---|---|
| 107 | 1246 |

Comment: Sheiko [107] used a platinum sphere as the oscillating bob.

TABLE 4. KF

| $T$ | $\eta$ (cp) |
|---|---|
| 1246.2 | 1.59 |

Viscosity: [107].

## LiF

### Viscosity

The recommended values in table 6 are based on the work of Vetyukov and Sipriya (oscillating sphere method) [108].

TABLE 5 A. Investigations critically re-examined

| Ref. | Temp. range ($T$) |
|---|---|
| 18 | 1073 |
| 108 | 1140–1348 |

TABLE 5 B. Cell materials and calibration

| Cell materials | Calibration |
|---|---|
| Pd-ball and Mo-suspension wire [108] | Sodium cryolite was used to check the method [108] |

### Melt Preparation and Purification

Vetyukov and Sipriya [108] used analytically pure LiF, heated at 600 °C for 3 h before using.

TABLE 6. LiF

$\eta = 1.8549 \cdot 10^{-1} \cdot \exp(5610/RT)$ (cp)

Stand. error of est.: 0.0157 = 0.86%

| $T$ | $\eta$ |
|---|---|
| 1140 | 2.21 |
| 1160 | 2.11 |
| 1180 | 2.03 |
| 1200 | 1.95 |
| 1220 | 1.88 |
| 1240 | 1.81 |
| 1260 | 1.74 |
| 1280 | 1.68 |
| 1300 | 1.63 |
| 1320 | 1.57 |
| 1340 | 1.53 |

Viscosity: [18, 108].

## NaF

### Density

The recommended values in table 9 are based on the work of Paucirova, Matiasovsky, and Malinovsky (Archimedean method) [**95**] and supersede the recommendation given in NSRDS–NBS–15 (Molten Salts: Vol. 1) [1].

TABLE 7 A. Additional investigations* critically re-examined

| Ref. | Temp. range ($T$) |
|---|---|
| 106 | 1290, 1392, 1487 |
| 115 | 1273 (graphical) |
| 96** | 1273, 1373 (graphical) |
| 45 | 1273–1349 |
| 7 | 1283–1393 |
| 26 | 1573 |
| 75 | 1273, 1323, 1373 |
| 24 | 1303–1363 |
| 97 | 1273 |
| 5 | 1288–1473 |
| 94 | 1273 |
| **95** | 1273–1373 |
| 49*** | 1283–1403 |
| 87 | 1273 (graphical) |
| 98 | 1273–1353 |
| 103 | 1273–1373 (graphical) |

*Refer to reference [1] for previous work
**Data taken from references [5, 7].
***Data taken from references [62, 10].

TABLE 7 B. Comparison with previous recommendations

| Ref. | Recommended Value | | % Departure | | | |
|---|---|---|---|---|---|---|
| | Vol. | Page | % (min) | ($T$) | % (max) | ($T$) |
| 106 | 1 | 3 | −0.03 | (1290–1392) | | |
| 7 | 1 | 3 | 0.56 | (1383) | 0.95 | (1283) |
| 75 | 1 | 3 | −0.04 | (1323) | −0.24 | (1373) |
| 24 | 1 | 3 | 0.06 | (1320) | −0.50 | (1360) |
| 97 | 1 | 3 | −0.51 | (1273) | | |
| 5 | 1 | 3 | 0.42 | (1398) | 0.84 | (1288) |
| 94 | 1 | 3 | 0.16 | (1273) | | |
| **95** | 1 | 3 | −0.02 | (1320) | −0.18 | (1360) |
| 98 | 1 | 3 | −2.23 | (1280) | −2.47 | (1350) |
| 45 | 1 | 3 | 0.63 | (1340) | 0.75 | (1280) |

TABLE 7 C. Cell materials and calibration

| Cell materials | Calibration |
|---|---|
| Pt-sinker and suspension wire [106, 45] | Volume calculated using coefficient of expansion of Pt [106, 45] |
| Pt spherical bob [5, 7, 97], Pt-ball [26] | Volume of ball determined from measurements on substances of known density [26] |
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [24, 98] | Molten KCl [24, 98] |
| Pt sinker and suspension wire, melt in Pt crucible [75, 94, **95**] | Molten NaCl and KCl [75, 94, **95**] |

Comment: Details concerning the density measurements by Paucirova et al. [**95**] are discussed under the system $AlF_3$–NaF.

### Viscosity

The recommended values in table 9 are based on the work of Abramov (oscillating sphere method) [**5**].

TABLE 8 A. Investigations critically re-examined

| Ref. | Temp. range ($T$) |
|---|---|
| **5** | 1288–1473 |

TABLE 8 B. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Pt sphere and Mo suspension wire, melt contained in a Pt cup [5] | Water, aniline and sulfuric acid [5] |

Comment: Abramov [5] reported a standard deviation of ±2 percent.

### Melt Preparation and Purification

The melt preparation and purification described in the following references are discussed under the binary systems given in section 6.1.

| Ref. | Systems |
|---|---|
| 45 | $AlF_3$–NaF |
| 75 | $AlF_3$–NaF |
| 5 | $AlF_3$–NaF |
| 94 | $AlF_3$–NaF |
| 95 | $AlF_3$–NaF |
| 98 | $CaF_2$–LiF |
| 24 | LiF–$ThF_4$ |

TABLE 9. NaF

$\rho = 2.7550 - 6.36 \cdot 10^{-4} T$ ($gcm^{-3}$)

$\eta = 3.970 \cdot 10^{-2} \cdot \exp(9831/RT)$ (cp)

Stand. error of est. for $\eta$: 0.0190 = 1.33%

| $T$ | $\rho$ | $\eta$ |
|---|---|---|
| 1280 | 1.941 | |
| 1290 | 1.935 | 1.84 |
| 1300 | 1.928 | 1.79 |
| 1310 | 1.922 | 1.73 |
| 1320 | 1.915 | 1.69 |
| 1330 | 1.909 | 1.64 |
| 1340 | 1.903 | 1.59 |
| 1350 | 1.896 | 1.55 |
| 1360 | 1.890 | 1.51 |
| 1370 | 1.884 | 1.47 |
| 1380 | | 1.43 |
| 1390 | | 1.40 |
| 1400 | | 1.36 |
| 1410 | | 1.33 |
| 1420 | | 1.29 |
| 1430 | | 1.26 |
| 1440 | | 1.23 |
| 1450 | | 1.20 |
| 1460 | | 1.18 |
| 1470 | | 1.15 |

Density: [5, 7, 24, 26, 45, 49, 75, 87, 94, 95, 96, 97, 98, 103, 106, 115].

Viscosity: [5].

## RbF

### Density

The recommended values in table 11 are based on the work of Jaeger et al. (Archimedean method [62] and [106], respectively.

TABLE 10 A. Investigations critically re-examined

| Ref. | Temp. Range |
|---|---|
| 62 | 1076–1359 |
| 106 | 1093–1279 |

TABLE 10 B. Cell materials and calibration

| Cell Materials | Calibration |
|---|---|
| Pt-sinker and Pt-suspension wire [62, 106] | Volume calculated using coefficient of expansion of Pt [62, 106] |

Comment: The melting point of RbF in reference [62] was found to be 760 ° C and at 1000 ° C a markable evaporation was observed.

TABLE 11. RbF

$\rho = 3.9953 - 1.0211 \cdot 10^{-3}$ T ($gcm^{-3}$)

Stand. error of est.: 0.0019 = 0.07%

| $T$ | $\rho$ |
|---|---|
| 1080 | 2.893 |
| 1100 | 2.872 |
| 1120 | 2.852 |
| 1140 | 2.831 |
| 1160 | 2.811 |
| 1180 | 2.790 |
| 1200 | 2.770 |
| 1220 | 2.750 |
| 1240 | 2.729 |
| 1260 | 2.709 |
| 1280 | 2.688 |
| 1320 | 2.668 |
| 1340 | 2.647 |

Density: [62, 106]

## $UF_4$

### Viscosity

The recommended values in table 13 are based on the work of Kulifeev et al. (oscillating hollow cylinder method) [69].

TABLE 12 A. Investigations critically re-examined

| Ref. | Temp. Range ($T$) |
|---|---|
| 69 | 1338–1618 |

TABLE 12 B. Cell material and calibration

| Cell material |
|---|
| Graphite crucible, W-suspension wire [69] |

Comment: Kulifeev [69] applied a closed crucible with an Argon atmosphere of 100 mm Hg-pressure to prevent evaporation of $UF_4$. An accuracy of ±10 percent was reported.

### Melt Preparation and Purification

Kulifeev and Panchisnyi [69] purified $UF_4$ by heating the salt with $NH_4HF_2$ at 800 to 900 K. The oxide impurities did not exceed 0.08 wt. percent.

TABLE 13. $UF_4$

| $T$ | $\eta^*$ (cp) |
|---|---|
| 1338 | 2.460 |
| 1348 | 2.010 |
| 1398 | 1.606 |
| 1433 | 1.348 |
| 1448 | 1.308 |
| 1488 | 1.272 |
| 1618 | 1.122 |

*The one-dimensional statistical analysis resulted in a Stand. Error of Est. of about 10 percent, therefore the experimental values are given.

Viscosity: [69].

## 5.4. General Summary Tables

TABLE 13 a. Total and recommended investigations [a]

| Compound | $\kappa$ | | $\rho$ | | $\eta$ | | $\gamma$ | |
|---|---|---|---|---|---|---|---|---|
| | No. of Invest. | Rec. Ref. | No. of Invest. | Rec. Ref. | No. of Invest. | Rec. Ref. | No. of Invest. | Rec. Ref. |
| AgF | 1 | [1] | | | | | | |
| $BaF_2$ | | | 5 | [1] | | | | |
| $BeF_2$ | 1 | [1] | 3 | [33, 73] | 5 | [1] | | |
| $CaF_2$ | | | 2 | [1] | | | | |
| $CeF_3$ | | | 1 | [1] | | | | |
| CsF | 2 | [1] | 4 | [1] | | | 3 | [2] |
| $CuF_2$ | 1 | [1] | | | | | | |
| KF | 14 | [1] | 10 | [1] | 1 | [107] | 4 | [2] |
| $LaF_3$ | | | 1 | [1] | | | | |
| LiF | 15 | [1] | 17 | [1] | 2 | [108] | 4 | [2] |
| $MgF_2$ | | | 1 | [1] | | | | |
| $MnF_2$ | 1 | [1] | | | | | | |
| NaF | 21 | [1] | 17 | [95] | 1 | [5] | 6 | [2] |
| $PbF_2$ | 1 | [1] | | | | | | |
| RbF | | | 2 | [62, 106] | | | 2 | [2] |
| $SrF_2$ | | | 1 | [1] | | | | |
| $ThF_4$ | | | 4 | [1] | | | 1 | [2] |
| $UF_4$ | | | 4 | [1] | 1 | [69] | 2 | [2] |
| $UF_6$ | | | | | | | 1 | [2] |
| $ZnF_2$ | 1 | [1] | | | | | | |

[a] Total number of investigations and recommended references for specific conductance, density, viscosity, and surface tension of single fluoride melts.

TABLE 13 b. References.[a]

Specific conductance

| Single salts | No. of invest. | Literature references |
|---|---|---|
| KF | 14 | **1**, 13, 14, 15, 89, **107**, 120 |
| LiF | 15 | **1**, 13, 16, 24, 40, 76, 78, 79, 80, 84, 87, 120 |
| NaF | 21 | **1**, 5, 8, 13, 24, 41, 50, 59, 66, 70, 76, 78, 79, 80, 87, 110, 120 |

[a] The total number of investigations evaluated and literature references that were not given in NSRDS–NBS–15 [1] and NSRDS–NBS–28 [2].

Table 13 c. References [a]

Density

| Single salts | No of invest. | Literature references |
|---|---|---|
| $BaF_2$ | 5 | **1**, 9, 26, 27, 118 |
| $BeF_2$ | 3 | **32**, **33**, 73 |
| CsF | 4 | **1**, 26, 106 |
| KF | 10 | **1**, 26, 27, 87, 89, 98, 106, 107 |
| LiF | 17 | **1**, 16, 18, 24, 26, 32, 60, 75, 84, 87, 89, 95, 98, 106, 108 |
| NaF | 17 | **1**, 5, 7, 24, 26, 45, 49, 75, 87, 94, **95**, 96, 97, 98, 103, 106 |
| RbF | 2 | **62**, 106 |
| $ThF_4$ | 4 | **1**, 31, 60, 98 |
| $UF_4$ | 4 | **1**, 69, 87, 98 |

[a] The total number of investigations evaluated and literature references that were not given in NSRDS–NBS–15 [1] and NSRDS–NBS–28 [2].

TABLE 13 d. References [a]

Viscosity

| Single salts | No. of invest. | Literature references |
|---|---|---|
| $BeF_2$ | 5 | **1**, 32, 33, 91 |
| KF | 1 | **107** |
| LiF | 2 | 18, **108** |
| NaF | 1 | **5** |
| $UF_4$ | 1 | **69** |

[a] The total number of investigations evaluated and literature references that were not given in NSRDS–NBS–15 [1] and NSRDS–NBS–28 [2].

TABLE 13 e. References.[a]

Surface tension

| Single salt | No. of invest. | Literature references |
|---|---|---|
| CsF | 3 | **2**, 68 |
| KF | 4 | **2**, 61, 89, 106 |
| LiF | 4 | **2**, 61, 89 |
| NaF | 6 | **2**, 5, 43, 61 |
| RbF | 3 | **2**, 61 |
| $UF_4$ | 2 | **2**, 69 |

[a] The total number of investigations evaluated and literature references that were not given in NSRDS–NBS–15 [1] and NSRDS–NBS–28 [2].

## 6. Binary Mixtures

### 6.1. Discussions and Numerical Data

This section comprises a discussion of the investigated transport properties featuring references, composition and temperature ranges, percent departure values, and experimental techniques. The melt preparation and purification section summarizes the procedures used in each investigation. Numerical tables of physical properties at rounded or experimental compositions and temperatures, together with temperature and composition-dependent equations are given for the recommended studies. Phase diagrams for each binary mixture are reported as an aid to the user.

## $AlF_3$-CsF

### Density

The recommended values in table 15 are based on the work of Mal'tsev and Bukhalova (Archimedean method) [25].

TABLE 14 A. Investigations critically re-examined

| Ref. | CsF (mol %) | Temp. range ($T$) |
|---|---|---|
| **25** | 75 | 1123–1273 |
| 74 | 75 | 1123–1223 |

TABLE 14 B. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Pt ball and suspension wire [25, 74] | Molten NaF, NaCl, KCl [25, 74] |

### Melt Preparation and Purification

Mal'tsev and Bukhalova [25, 74] for the preparation of $Cs_3AlF_6$ reported only that the synthesis was carried out by fusion of analytical grade CsF and $AlF_6$.

TABLE 15 a. $AlF_3$-CsF: Density

Numerical Values ($gcm^{-3}$)

| $T$ | 75 Mol % CsF |
|---|---|
| 1130 | 3.046 |
| 1140 | 3.031 |
| 1150 | 3.015 |
| 1160 | 3.000 |
| 1170 | 2.985 |
| 1180 | 2.969 |
| 1190 | 2.954 |
| 1200 | 2.939 |
| 1210 | 2.923 |
| 1220 | 2.908 |
| 1230 | 2.893 |
| 1240 | 2.877 |
| 1250 | 2.862 |
| 1260 | 2.846 |
| 1270 | 2.831 |

TABLE 15 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % CsF) | $a$ | $b \cdot 10^3$ | Stand. error of est. |
|---|---|---|---|
| 75 | 4.7793 | −1.5340 | 0.0003 |

Reference: [25]. Data reported in numerical form.

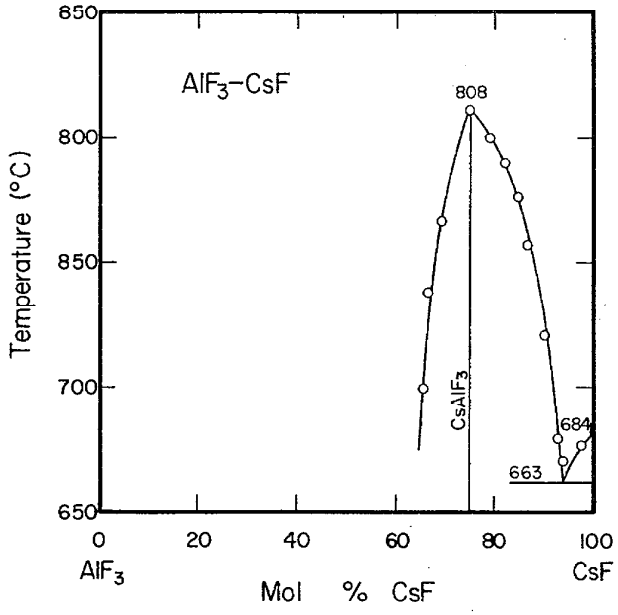


FIGURE 1. Temperature-composition phase diagram for $AlF_3$-CsF. E. P. Dergunov, Dan S.S.S.R., **60**, 1185 (1948).

## $AlF_3$-KF

### Electrical Conductance

The recommended values in figure 2 are based on the work of Yim and Feinleib (classical ac technique) [**120**].

TABLE 16 A. Investigations critically re-examined

| Ref. | KF (mol %) | Temp. range (*T*) |
|---|---|---|
| **120** | 75, 100 (graphical except for 100% at 1173 K) | 1153–1343 |
| 15 | 60–100 | 1133–1323 |
| 100* | 75 | 1273, 1333 |
| 14 | 75 | 1273, 1298, 1322 |

*Values from reference [**120**].

TABLE 16 B. Comparisons with previous recommendations

| Ref. | Recommended value | | KF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (*T*) | % (max) | (*T*) |
| **120** | 1 | 3 | 100 | 3.3 | (1173) | | |
| 15 | 1 | 3 | 100 | 14.1 | (1153) | 22.5 | (1248) |

TABLE 16 C. Cell materials and calibration

| Cell Material | Electrodes | Frequency Range (Hz) | Calibration |
|---|---|---|---|
| Boron nitride cell inside graphite crucible [**120**] | Inconel [**120**] | 1,000–20,000 measurements at 2000 [**120**] | Calculated from dimensions of electrodes or/ molten KCl [**120**] |
| Pt crucible [14] | Pt [14] | | KCl solution [14] |

Comment: Yim and Feinleib [**120**] corrected for the conductance of the boron nitride cell body by measuring both the combined conductance of the electroyte and cell body and then the conductance of the empty cell. Since boron nitride is rapidly oxidized at about 1000 ° C, all measurements were made in an argon atmosphere. Polarization was not considered a problem since resistance readings did not vary appreciably between 1,000 and 20,000 hertz.

Measurements were reported to be reproducible to about 1–2 percent.

### Density

The recommended values in table 18 are based on the work of Mal'tsev and Bukhalova (Archimedean method) [**74**].

TABLE 17 A. Investigations critically re-examined

| Ref. | KF (mol %) | Temp. range (*T*) |
|---|---|---|
| 25 | 75 | 1073 |
| **74** | 75 | 1273, 1323 |

TABLE 17 B. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Pt ball and wire [25, **74**] | Molten NaF, KCl, NaCl [25, **74**] |

Comment: No correction for surface tension was applied in references [25, **74**].

### Melt Preparation and Purification

Yim and Feinlieb [**120**] used Baker's reagent grade KF. The preparation of pure $AlF_3$ is described under the system $AlF_3$-LiF. The preparation of pure $AlF_3$ and KF (similar to NaF) by Batashev [14, 15] is given under the $AlF_3$-NaF system.

Mal'tsev and Bukhalova [25, **74**] synthesized $K_3AlF_6$ by fusion of KF with $AlF_3$. Salts of analytical grade were used for synthesis.

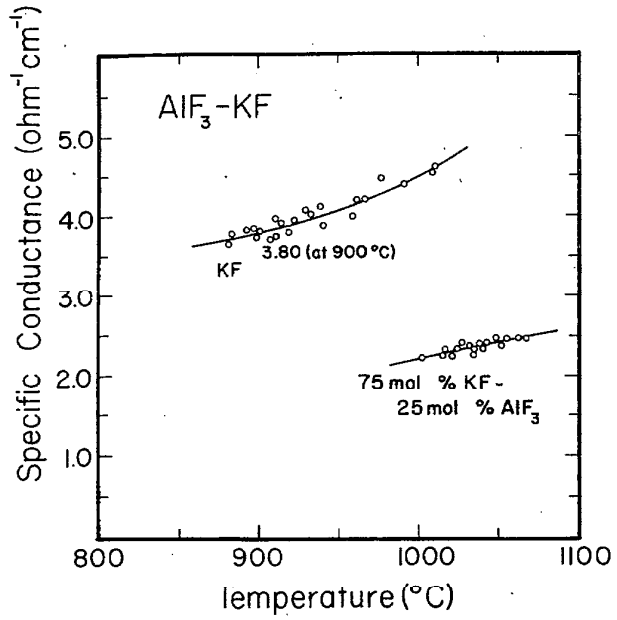


FIGURE 2. Plots [120] of specific conductance against temperature for the system $AlF_3$-KF.

TABLE 18. $AlF_3$-KF: Density

Numerical Values ($gcm^{-3}$)

| $T$ | 75 Mol % KF |
|---|---|
| 1273.2 | 1.828 |
| 1323.2 | 1.791 |

Reference: [74].
Due to limited data the experimental values are given.

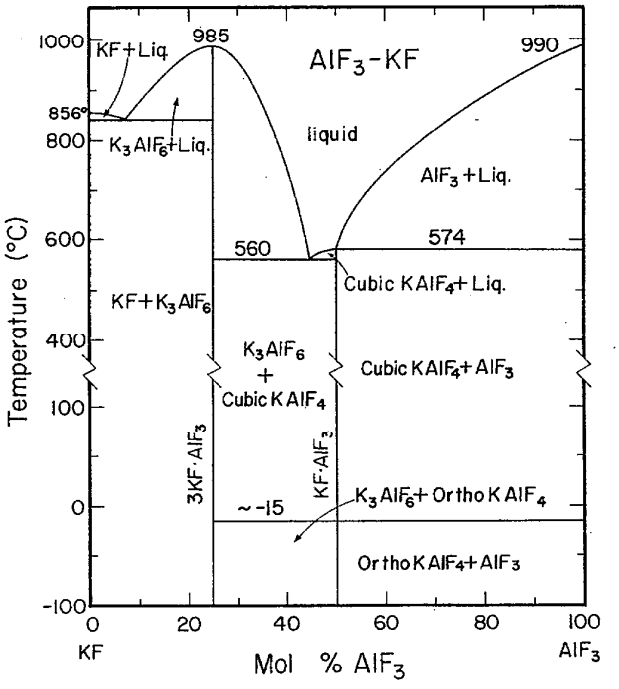


FIGURE 3. Temperature-composition phase diagram for $AlF_3$-KF. Bert Phillip, C. M. Warsaw, and I. Mockrin, J. Am. Ceram. Soc., 49 [12] 633 (1966).

## $AlF_3$-LiF

### Electrical Conductance

The recommended values in table 22 and figure 4 are based on the work of Matiasovsky et al.[8] (Classical ac technique) [80].

TABLE 19 A. Investigations critically re-examined

| Ref. | LiF (mol %) | Temp. Range ($T$) |
|---|---|---|
| 120 | 75, 100 (graphical for 75 mol % LiF) | 1063–1248 |
| **80** | 55–100 (numerical for 75 and 100 mol % LiF) | 1123–1323 |
| 40 | 25–100 (graphical) | 1073–1348 |
| 6 | 75 | 1098–1348 |
| 79 | 25–100 (graphical) | 1173, 1273, 1373 |
| 86 | 75 | 1073–1273 |
| 100* | 75 | 1073–1193 |
| 41 | 75 | 1153–1348 |
| 84 | 25–100 (graphical) | 1073, 1173, 1273 |
| 42 | 75 (graphical) | 1273, 1323, 1373 |
| 77 | 75 (graphical) | 1273, 1323 |

* Data from reference [120].

TABLE 19 B. Comparison with previous recommendations

| Ref. | Recommended value | | LiF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 120 | 1 | 2 | 100 | −4.2 | (1173) | | |
| **80** | 1 | 2 | 100 | 0.04 | (1260) | −3.7 | (1140) |
| 120 | 4.1 | 15 | 100 | −1.2 | (1173) | | |
| 6 | 4.1 | 15 | 75 | −2.0 | (1173) | −4.0 | (1323) |
| 86 | 4.1 | 15 | 75 | 12.4 | (1273) | | |

[8] These result have been further discussed recently. See K. Matiasovsky and V. Danek, J. Electrochem. Soc. 120, 919 (1973).

TABLE 19 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) | Calibration |
|---|---|---|---|
| Boron nitride cell inside a graphite crucible [120] | Inconel [120] | 1,000–70,000 (measurements at 2,000) [120] | Measurements of cell dimensions and molten KCl [120] |
| Pt crucible [6, 40, 41, 79, **80**] | Pt [6, 40, 41, 79, **80**, 86] | 4,000–20,000 (measurements at 18,000) [6, 40, 41, 79, **80**] | Molten $Na_3AlF_6$ [6, 40, 41, 79, **80**] |
| Pt crucible [86] | Mo [84] | 5,500 [86] | 0.1 N KCl solution at 18 ° C [86] |
| Boron nitride cell inside graphite holder [84] | | 1,000–20,000 [84] | |

Comments: The conductance of the boron nitride cell body used in reference [119, 120] was corrected by measuring the combined conductance of the electroyte and the cell, and then lifting the cell out of the melt and determining the "empty cell conductance." Yim and Feinleib [119, 120] reported that reproducibility between runs was usually 2 percent or better.

Matiasovsky et al reported an overall error of less than ±2 percent for conductivity measurements. Mashovets and Petrov [86] estimated their accuracy at ±3 percent.

## Density

The recommended values in table 23 are based on the work of Matiasovsky et al. (Archimedean method) [**75, 95**].

TABLE 20 A. Investigations critically re-examined

| Ref. | LiF (mol %) | Temp. range ($T$) |
|---|---|---|
| **75** | 55 –100 | 1123–1323 |
| 86 | 75 | 1061–1302 |
| 108 | 65 –100 | 1140–1398 |
| 94 | 55 –100 | 1273 |
| **95** | 55 –100 | 1123–1323 |
| 84 | 37.5–100 | 1073, 1273 |
| 74 | 75 | 1073–1273 |
| 83 | 75 | 1283–1348 |

Two references from the same laboratory were weighted equally. Reference [95] is based on the numerical results received as a private communication [75]; in [95] numerical values are not reported, but rather the results are presented as a set of smoothed equations. The recommended values advanced herewith are based on the numerical results (ref. 75).

TABLE 20 B. Comparison with Previous Recommendations

| Ref. | Recommended value | | LiF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| **75** | 1 | 2 | 100 | −0.11 | (1273) | −0.17 | (1173) |
| 94 | 1 | 2 | 100 | −0.11 | (1273) | | |
| **95** | 1 | 2 | 100 | −0.36 | (1140) | −0.18 | (1300) |
| 108 | 1 | 2 | 100 | −0.64 | (1348) | −1.2 | (1188) |
| 84 | 1 | 2 | 100 | −2.8 | (1273) | | |
| 108 | 4.1 | 16 | 100 | −0.53 | (1348) | −0.90 | (1188) |
| 84 | 4.1 | 16 | 100 | −2.8 | (1273) | | |
| 84 | 4.1 | 16 | 95 | 3.6 | (1273) | | |
| 108 | 4.1 | 16 | 90 | −0.90 | (1276) | −0.94 | (1238) |
| 84 | 4.1 | 16 | 90 | 3.7 | (1273) | | |
| 84 | 4.1 | 16 | 80 | −0.20 | (1273) | | |
| 86 | 4.1 | 16 | 75 | 2.7 | (1273) | | |
| 108 | 4.1 | 16 | 75 | −0.90 | (1241) | −0.94 | (1340) |
| 84 | 4.1 | 16 | 75 | −0.97 | (1273) | | |
| 74 | 4.1 | 16 | 75 | −0.48 | | −2.5 | |
| 108 | 4.1 | 16 | 70 | −0.77 | (1289) | −0.80 | (1236) |
| 108 | 4.1 | 16 | 65 | −0.69 | (1277) | −1.07 | (1207) |
| 84 | 4.1 | 16 | 60 | 6.4 | (1273) | | |

TABLE 20 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Pt sinker and suspension wire [74, **75**, 83, 94, **95**] | Molten KCl, NaCl [74, **75**, 83, 94, **95**] |

Comment: Matiasovsky et al. [74, **75**, 83, 94, **95**] found that volumes of the Pt sinker determined from molten KCl and NaCl differed by less than 0.2 percent. The reproducibility of measurements was reported to be better than 0.1 percent.

## Viscosity

The recommended values in table 25 are based on the work of Vetyukov and Sipriya (oscillating sphere method) [**108**].

TABLE 21 A. Investigations critically re-examined

| Ref. | LiF (mol %) | Temp. range ($T$) |
|---|---|---|
| **108** | 65–100 | 1140–1398 |

### Melt Preparation and Purification

Yim and Feinleib [119, 120] used Baker's reagent grade LiF. Aluminium fluoride was Alcoa X–2A grade powder containing approximately 97 percent $AlF_3$, 1.2 percent NaF and 1.5 percent $Al_2O_3$. The material was not sublimed. Mixtures were prepared by mixing the melt constituents in the dry state followed by fusion in a graphite crucible. The melt was cooled, pulverized, thoroughly mixed, and sampled.

Abramov et al. [6] used sublimation techniques to purify technical grade $AlF_3$. The LiF was heated to 1100 °C to remove moisture.

Lithium cryolite, used in reference [86] was synthetically prepared from chemically-pure lithium and aluminium fluoride. The composition was checked by chemical analysis and optical crystallography.

Vetyukov and Sipriya [108] used analytically pure LiF and c.p. $AlF_3$. Before using, LiF was heated at 600 °C for 3 h and $AlF_3$ was heated at 300 °C for 3 h.

TABLE 22a. $AlF_3$–LiF: Electrical Conductance

Specific Conductance: Numerical Values ($ohm^{-1}$ $cm^{-1}$)

Mol percent LiF

| $T$ | 100 | 75 |
|---|---|---|
| 1130 | 8.20 | |
| 1140 | 8.28 | |
| 1150 | 8.35 | |
| 1160 | 8.42 | |
| 1170 | 8.50 | |
| 1180 | 8.57 | 4.02 |
| 1190 | 8.64 | 4.04 |
| 1200 | 8.71 | 4.06 |
| 1210 | 8.78 | 4.08 |
| 1220 | 8.85 | 4.10 |
| 1230 | 8.91 | 4.12 |
| 1240 | 8.98 | 4.14 |
| 1250 | 9.04 | 4.15 |
| 1260 | 9.11 | 4.17 |
| 1270 | 9.17 | 4.18 |
| 1280 | 9.23 | 4.20 |
| 1290 | 9.29 | 4.21 |
| 1300 | 9.35 | 4.23 |
| 1310 | 9.41 | 4.24 |
| 1320 | 9.46 | 4.25 |

TABLE 22 b. Temperature-dependent equations

$\kappa = a + bT + cT^2$ ($ohm^{-1}$ $cm^{-1}$)

| Comp. (mol % LiF) | $a$ | $b \cdot 10^3$ | $c \cdot 10^6$ |
|---|---|---|---|
| 75 | −3.3489 | 10.3337 | −3.4658 |
| 100 | −7.6069 | 20.2557 | −5.5475 |

Reference: [80]. Data reported in equation form. Additional data are reported graphically in figure 4.

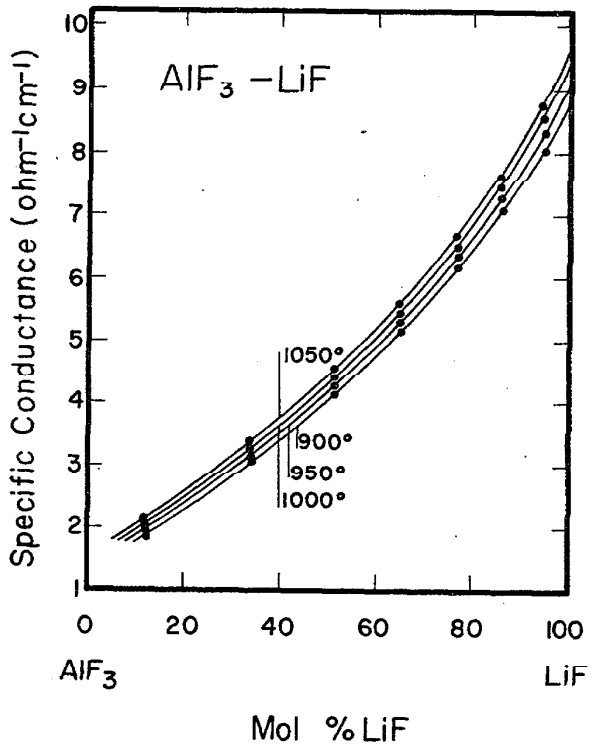


FIGURE 4. Isotherms [80] (°C) of specific conductance against molar composition for the system $AlF_3$-LiF.

TABLE 23. $AlF_3$-LiF: Density

Numerical values ($gcm^{-3}$)

Mol percent LiF

| $T$ | 100 | 95 | 90 | 85 | 80 | 75 | 70 | 65 | 60 | 55 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1130 | 1.800 | 1.885 | 1.972 | 2.037 | 2.073 | 2.098 | 2.088 | 2.041 | 1.962 | 1.861 |
| 1140 | 1.795 | 1.880 | 1.966 | 2.030 | 2.065 | 2.089 | 2.079 | 2.031 | 1.952 | 1.851 |
| 1150 | 1.791 | 1.875 | 1.960 | 2.023 | 2.058 | 2.081 | 2.069 | 2.021 | 1.942 | 1.842 |
| 1160 | 1.786 | 1.870 | 1.953 | 2.016 | 2.051 | 2.073 | 2.060 | 2.010 | 1.931 | 1.832 |
| 1170 | 1.781 | 1.866 | 1.947 | 2.010 | 2.044 | 2.064 | 2.051 | 2.000 | 1.921 | 1.823 |
| 1180 | 1.777 | 1.861 | 1.941 | 2.003 | 2.037 | 2.056 | 2.041 | 1.990 | 1.911 | 1.814 |
| 1190 | 1.772 | 1.856 | 1.935 | 1.996 | 2.030 | 2.048 | 2.032 | 1.979 | 1.901 | 1.805 |
| 1200 | 1.767 | 1.851 | 1.929 | 1.990 | 2.023 | 2.039 | 2.022 | 1.969 | 1.891 | 1.795 |
| 1210 | 1.763 | 1.846 | 1.923 | 1.983 | 2.016 | 2.031 | 2.013 | 1.959 | 1.880 | 1.786 |
| 1220 | 1.758 | 1.842 | 1.917 | 1.976 | 2.009 | 2.022 | 2.004 | 1.948 | 1.870 | 1.776 |
| 1230 | 1.753 | 1.837 | 1.910 | 1.970 | 2.002 | 2.014 | 1.994 | 1.938 | 1.860 | 1.767 |
| 1240 | 1.748 | 1.832 | 1.904 | 1.963 | 1.994 | 2.006 | 1.985 | 1.928 | 1.850 | 1.758 |
| 1250 | 1.744 | 1.827 | 1.898 | 1.956 | 1.987 | 1.997 | 1.976 | 1.918 | 1.840 | 1.748 |
| 1260 | 1.739 | 1.822 | 1.892 | 1.950 | 1.980 | 1.989 | 1.966 | 1.907 | 1.829 | 1.739 |
| 1270 | 1.734 | 1.817 | 1.886 | 1.943 | 1.973 | 1.981 | 1.957 | 1.897 | 1.819 | 1.729 |
| 1280 | 1.730 | 1.813 | 1.880 | 1.936 | 1.966 | 1.972 | 1.948 | 1.887 | 1.809 | 1.720 |
| 1290 | 1.725 | 1.808 | 1.874 | 1.929 | 1.959 | 1.964 | 1.938 | 1.876 | 1.799 | 1.711 |
| 1300 | 1.720 | 1.803 | 1.867 | 1.923 | 1.952 | 1.956 | 1.929 | 1.866 | 1.789 | 1.701 |
| 1310 | 1.716 | 1.798 | 1.861 | 1.916 | 1.945 | 1.947 | 1.920 | 1.856 | 1.778 | 1.692 |
| 1320 | 1.711 | 1.793 | 1.855 | 1.909 | 1.938 | 1.939 | 1.910 | 1.845 | 1.768 | 1.682 |

TABLE 24. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % LiF) | $a$ | $b \cdot 10^4$ | Stand. error of est. |
|---|---|---|---|
| 55 | 2.9235 | −9.4019 | 0.0006 |
| 60 | 3.1147 | −10.2009 | 0.0000 |
| 65 | 3.2050 | −10.2998 | 0.0003 |
| 70 | 3.1456 | −9.3597 | 0.0003 |
| 75 | 3.0422 | −8.3590 | 0.0003 |
| 80 | 2.8751 | −7.1021 | 0.0004 |
| 85 | 2.7935 | −6.6981 | 0.0003 |
| 90 | 2.6660 | −6.1429 | 0.0003 |
| 95 | 2.4298 | −4.8222 | 0.0007 |
| 100 | 2.3283 | −4.6757 | 0.0000 |

Reference: [75]. Data reported in numerical form.

TABLE 25 a. $AlF_3$-LiF: Viscosity

Numerical values (cp)

Mol percent LiF

| $T$ | 100.0 | 90.0 | 77.5 | 75.0 | 70.0 | 65.0 |
|---|---|---|---|---|---|---|
| 1150 | 2.16 | | | | | |
| 1160 | 2.11 | | | | | |
| 1170 | 2.07 | | | | | |
| 1180 | 2.03 | | [2.81] | 3.01 | | |
| 1190 | 1.99 | | [2.72] | 2.89 | | |
| 1200 | 1.95 | | [2.64] | 2.78 | | |
| 1210 | 1.91 | | [2.55] | 2.67 | | [2.01] |
| 1220 | 1.88 | | [2.47] | 2.56 | | [1.93] |
| 1230 | 1.84 | | [2.40] | 2.47 | | [1.86] |
| *1240* | *1.81* | *[1.90]* | *[2.32]* | 2.38 | 2.15 | *[1.79]* |
| 1250 | 1.77 | [1.88] | [2.24] | 2.29 | 2.06 | [1.73] |
| 1260 | 1.74 | [1.85] | [2.16] | 2.21 | 1.99 | [1.68] |
| 1270 | 1.71 | [1.82] | [2.09] | 2.13 | 1.91 | [1.62] |
| 1280 | 1.68 | [1.79] | [2.01] | 2.05 | 1.84 | [1.58] |
| 1290 | 1.65 | [1.75] | [1.93] | 1.98 | 1.78 | [1.53] |
| 1300 | 1.63 | [1.72] | [1.84] | 1.92 | 1.72 | [1.49] |
| 1310 | 1.60 | [1.68] | [1.76] | 1.85 | 1.66 | [1.45] |
| 1320 | 1.57 | [1.64] | [1.67] | 1.79 | 1.60 | [1.41] |
| 1330 | 1.55 | [1.60] | [1.58] | 1.73 | 1.55 | [1.37] |
| 1340 | 1.53 | [1.56] | [1.48] | 1.68 | 1.50 | |
| 1350 | | [1.52] | [1.38] | | 1.45 | |
| 1360 | | [1.49] | | | 1.40 | |
| 1370 | | [1.46] | | | 1.36 | |
| *1380* | | *[1.43]* | | | *1.31* | |
| 1390 | | [1.40] | | | | |

TABLE 25 b. Temperature-dependent equations

$\eta = a + bT + cT^2 + dT^3$ (cp)

$\eta = A \cdot \exp(E/RT)$ (cp)

| Comp. (mol % LiF) | $a \cdot 10^{-1}$ | $b \cdot 10^2$ | $c \cdot 10^4$ | $d \cdot 10^7$ | $A \cdot 10^2$ | $E$ (cal $mol^{-1}$) | Stand. error of est. |
|---|---|---|---|---|---|---|---|
| 65.0 | [ 22.0537] | [−48.3987] | [ 3.5890] | [−0.8940] | | | 0.0000 |
| 70.0 | | | | | 1.691 | 11934 | 0.0235 |
| 75.0 | | | | | 2.240 | 11491 | 0.0551 |
| 77.5 | [ 16.0675] | [−36.5688] | [ 2.8710] | [−0.7676] | | | 0.0000 |
| 90.0 | [−22.7452] | [ 52.8134] | [−4.0281] | [ 1.0166] | | | 0.0000 |
| 100.0 | | | | | 18.549 | 5610 | 0.0157 |

Reference: [108]. Data reported in numerical form.

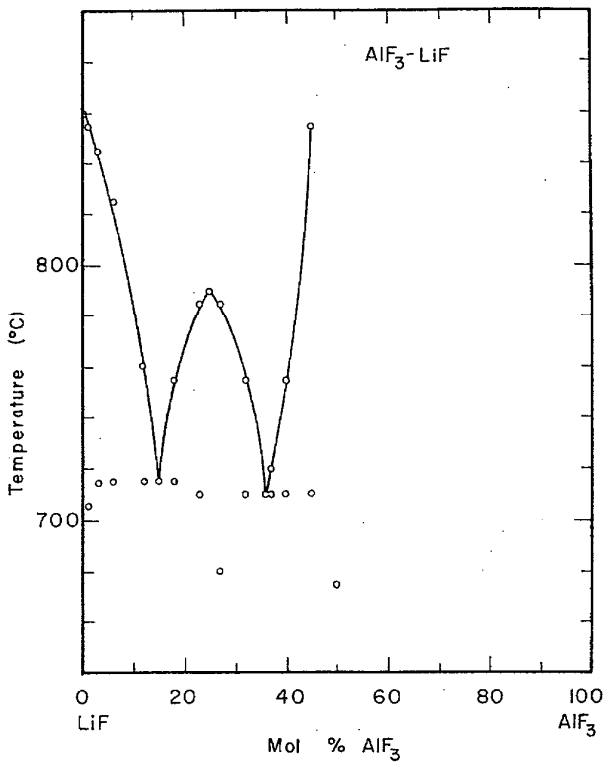


FIGURE 5. Temperature-composition phase diagram for $AlF_3$-LiF. P. P. Fedotjeff and K. Timofeeff, Z. Anorg. Allg. Chem., **206**, 263 (1932).

## $AlF_3$-NaF
### Electrical Conductance

The recommended values in table 30 are based on the work of Edwards et al. (classical ac technique) [**45, 46**].

TABLE 26 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. Range ($T$) |
|---|---|---|
| 96 | 40–100 (graphical) | 1273 |
| 14 | 53.4–100 | 1023–1323 |
| **45** | 67.6–100 | 1273, 1313, 1353 |
| 85 | 75 | 1273 |
| 39 | 75 | 1293 |
| 116 | 75 | 1273, 1297, 1323 |
| 10 | 75 | 1253–1313 |
| 80 | 75, 100 (graphical for 75 mol %) | 1273–1373 |
| 40 | 75 (graphical) | 1273–1323 |
| 6 | 75 | 1273–1423 |
| 79 | 75, 100 (graphical for 75 mol %) | 1273, 1323 |
| 86 | 75 (graphical except for 1273 K) | 1273–1423 |
| 120 | 70.9–100 (graphical) | 1173–1333 |
| 77 | 75 (graphical) | 1273, 1323 |
| 12 | 75 | 1273–1353 |
| 41 | 75, 100 (graphical) | 1273–1390 |
| 5 | 48.5–100 | 1003–1439 |
| 70 | 75, 100 (graphical) | 940–1523 |
| 82 | 75 (graphical) | 1273–1353 |
| 110* | 75 (graphical) | 1273 |
| 51** | 71.1–100 | 1273 |
| **46** | 75 | 1273–1353 |
| 104*** | 20–100 (graphical except for 75 mol %) | 1273–1353 |
| 114 | 63.5–100 (graphical for mixtures) | 1193–1411 |
| 81 | 75 (graphical) | 1273 |

*Values from reference [120].

**Values from references [45, 114, 120].

***Values from references [14, 45, 86, 114, 116, 120]. and see also K. Matiasovsky and V. Danek, J. Electrochem. Soc. **120**, 919 (1973).

TABLE 26 B. Comparisons with previous recommendations

| Ref. | Recommended value | | NaF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| 14 | 1 | 3 | 100 | −8.8 | (1323) | −18.8 | (1273) |
| 45 | 1 | 3 | 100 | 11.7 | (1273) | 15.1 | (1353) |
| 80 | 1 | 3 | 100 | 0.0 | (1370) | −1.9 | (1280) |
| 79 | 1 | 3 | 100 | 0.0 | (1370) | −1.9 | (1280) |
| 5 | 1 | 3 | 100 | −7.9 | (1390) | −9.4 | (1287) |
| 14 | 4.1 | 20 | 100 | −21.4 | (1313) | −27.4 | (1273) |
| 80 | 4.1 | 20 | 100 | −9.3 | (1313) | −15.7 | (1273) |
| 51 | 4.1 | 20 | 100 | −5.9 | (1273) | | |
| 14 | 4.1 | 20 | 75 | −15.4 | (1273) | −20.0 | (1313) |
| 85 | 4.1 | 20 | 75 | −21.4 | (1273) | | |
| 116 | 4.1 | 20 | 75 | −13.0 | (1323) | −15.7 | (1273) |
| 10 | 4.1 | 20 | 75 | −18.3 | (1313) | −20.4 | (1273) |
| 6 | 4.1 | 20 | 75 | −10.0 | (1273) | −11.4 | (1348) |
| 86 | 4.1 | 20 | 75 | −9.6 | (1273) | | |
| 5 | 4.1 | 20 | 75 | −5.2 | (1313) | −8.2 | (1283) |
| 14 | 4.1 | 20 | 70 | 13.8 | (1273) | | |

TABLE 26 C. Cell materials and calibration

| Cell Material | Electrodes | Frequency range (Hz) | Calibration |
|---|---|---|---|
| Pt crucible [10, 14] | Pt [6, 10, 12, 14, 40, 41, **45**, **46**, 70, 77, 79, 80, 82, 86] | 500–4000 [**45**, **46**] | KCl solution (18 ° C) [14] |
| Pt cell with cylindrical sides and hemispherical top and bottom, melt contained in Pt crucible [**45**, **46**] | Inconel [120] | 1,000–20,000 (measurements at 2,000) [120] | 31.1% $H_2SO_4$ and 0.01 N KCl [**45**, **46**], Molten KCl [120] |
| Boron nitride cell inside graphite crucible [120] | | 4,000–20,000 (measurements at 18,000) [6, 40, 77, 79, 80] | Molten $Na_3AlF_6$ [6, 40, 77, 79, 80] |
| Pt crucible with Pt disc electrodes [6, 12, 40, 41, 79, 80, 82] | | 5,000 [12, 82] | 30% $H_2SO_4$ [12] |
| Pt crucible with two hemispherical Pt electrodes [86] | | 5,500 [86] | Molten $KNO_3$, NaCl, $Na_2SO_4$ [82] |
| Pt crucible with inner cylindrical Pt electrode [70] | | | 0.1 N KCl (25 ° C) [10] |
| | | | 0.1 N KCl, 1 N KCl and 30% $H_2SO_4$ [86] |
| | | | KCl solution [70] |

Comment: Resistance readings in reference [**45** and **46**] were extrapolated to infinite frequency using plots of resistance versus frequency$^{-1/2}$. Attempts at determining the cell constant in molten NaCl and KCl were unsuccessful.

Comments concerning reference [120] are given under the system $AlF_3$–LiF.

Matiasovsky et al. [6, 40, 41, 79, 80, 82] used as a cell a platinum crucible with two Pt disc electrodes. The electrodes were positioned in the melt with the aid of a micrometer screw to an accuracy of ±0.01 mm. An overall error of ±2 percent for conductivity measurements was reported.

Mashovets and Petrov [86] estimated their measurements to be accurate to ±3 percent.

## Density

The recommended values in table 31 are based on the work of Matiasovsky et al. (Archimedean method) [**75**, **95**].

## Density

The recommended values in table 59 are based on the work of Blanke et al. (Archimedean method) [17].

TABLE 55 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range ($T$) |
|---|---|---|
| 35 | 50, 57, 70 | |
| 30* | 45, 50, 57 | |
| 19 | 21.9–81.2 | 873, 973, 1073 |
| 17** | 20–80 | 650–1170 |

*Data from [17].

**Numerical values at 873, 1073; graphical results for temp. range indicated.

TABLE 54 B. Cell materials and calibration

| Cell material |
|---|
| Pt cylinder and suspension wire, In crucible [17, 19] |

Comment: Blanke et al. [17] reported an overall error for density results of ±0.27 percent.

## Viscosity

The recommended values in tables 60, 61 are based on the work of Cohen et al. (capillary and rotating cylinder methods) [35] and Blanke et al. (rotating cylinder method) [19].

TABLE 56 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range ($T$) |
|---|---|---|
| 121* | 57 | 873 |
| 35 | 50, 57, 70 | 873, 973, 1073 |
| 56 | 57 | 727 |
| 19 | 21.9–81.7 | 873, 973, 1073 |

*Data from reference [35].

TABLE 56 B. Cell materials and calibration

| Cell material |
|---|
| Inner and outer cylinder of Inconel, Ni shaft and Mo torsion wire [19]. |

Comment: Cohen et al. [35] measured viscosities using a capillary viscometer as well as a modified Brookfield rotational device. Error limits for the experimental measurements were ±10 percent.

## Surface Tension

The recommended values in table 62 are based on the work of Mac Pherson (maximum bubble pressure method) [72].

TABLE 57 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range ($T$) |
|---|---|---|
| 72 | 57.1–62.0 | 773–1073 |

## Melt Preparation and Purification

Robbins and Braunstein [30] used hand picked, glass-clear crystals of recrystallized NaF and sublimed $BeF_2$ which were melted under an inert atmosphere into the conductance cell. Spectrographic analysis of the starting materials showed the major impurities to be (in ppm by weight) for $BeF_2$: 50 Li, 100 Na and for NaF: 2 Mg, 2 Fe, and 3 Ca.

Blanke et al. [17, 19] used analytical grade $BeF_2$ (Brush Beryllium Corporation) without further purification. NaF was analytical reagent grade and was dried at 200 to 230 °C for at least 24 hours before use. Salts were pulverized, weighed and mixed in a stainless steel drybox. Samples were melted in nickel crucibles and transferred into Inconel sample crucibles.

TABLE 58 a. $BeF_2$–NaF: Electrical conductance

Specific conductance: Numerical values ($ohm^{-1}$ $cm^{-1}$)

| | Mol percent NaF | | |
|---|---|---|---|
| $T$ | 57.0 | 50.0 | 45.0 |
| 630 | 0.1750 | | |
| 640 | 0.2032 | | 0.0915 |
| 650 | 0.2322 | | 0.1069 |
| 660 | 0.2620 | | 0.1232 |
| 670 | 0.2927 | 0.1867 | 0.1402 |
| 680 | 0.3243 | 0.2097 | 0.1581 |
| 690 | 0.3567 | 0.2337 | 0.1768 |
| 700 | 0.3899 | 0.2587 | 0.1964 |
| 710 | 0.4239 | 0.2845 | 0.2167 |
| 720 | 0.4588 | 0.3113 | 0.2379 |
| 730 | 0.4946 | 0.3391 | 0.2600 |
| 740 | 0.5312 | 0.3677 | 0.2828 |
| 750 | 0.5686 | 0.3973 | 0.3065 |
| 760 | 0.6068 | 0.4279 | 0.3310 |
| 770 | 0.6459 | 0.4593 | 0.3563 |
| 780 | 0.6859 | 0.4917 | 0.3825 |
| 790 | 0.7266 | 0.5251 | 0.4094 |
| 800 | 0.7682 | 0.5593 | 0.4372 |
| 810 | 0.8107 | 0.5946 | 0.4659 |
| 820 | 0.8540 | 0.6307 | 0.4953 |
| 830 | | | 0.5256 |

TABLE 58 b. Temperature-dependent equations

$\kappa = a + bT + cT^2$ ($ohm^{-1}$ $cm^{-1}$)

| Comp. (mol % NaF) | $a \cdot 10^1$ | $b \cdot 10^3$ | $c \cdot 10^6$ | Stand. error of est. |
|---|---|---|---|---|
| 45.0 | 8.2320 | −3.7865 | 4.1301 | 0.0011 |
| 50.0 | 7.6991 | −4.0005 | 4.6716 | 0.0007 |
| 57.0 | 0.9115 | −2.5105 | 4.1961 | 0.0038 |

Reference: [30]. Data reported in numerical form.

TABLE 59. $BeF_2$-NaF: Density

Numerical values ($gcm^{-3}$)

Mol percent NaF

| $T$ | 80 | 76 | 70 | 66.7 | 64 | 60 | 58 | 52.9 | 52 | 50 | 46 | 40 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 873.2 | | | 2.113 | 2.111 | 2.108 | 2.113 | 2.103 | 2.099 | 2.098 | 2.070 | 2.088 | 2.086 | |
| 1073.2 | 2.024 | 2.018 | 2.012 | 2.034 | 2.008 | 2.007 | 2.005 | 2.034 | 1.992 | 1.969 | 1.985 | 1.982 | 1.971 |

Reference [17]. Due to limited data the numerical interpolated values reported in rereference [17] are given.

TABLE 60. $BeF_2$-NaF: Viscosity

Numerical values (cp)

Mol percent NaF

| $T$ | 81.7 | 75 | 72.96 | 70 | 69.83 | 66.67 | 60 | 55.59 | 50 | 47.8 | 42.7 | 35.89 | 21.93 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 873.2 | | | | 4.98 | 5.03 | 9.04 | 9.59 | 9.92 | 14.58 | 17.19 | | | |
| 973.2 | | | 4.06 | 3.92 | 3.65 | 5.91 | | 5.68 | | 8.80 | 12.97 | 25.90 | |
| 1073.2 | 3.60 | 3.04 | 2.89 | 2.81 | 2.81 | 4.18 | 3.79 | 3.60 | 4.58 | 5.02 | 5.49 | 11.04 | 55.20 |

Reference: [19]. Due to limited data the numerical interpolated values reported in reference [19] are given.

TABLE 61. $BeF_2$-NaF: Viscosity

Numerical values (cp)

Mol percent NaF

| $T$ | 70 | 57 | 50 |
|---|---|---|---|
| 873.2 | 5.0 | 12.8 | 15.3 |
| 973.2 | 3.9 | 7.0 | 8.4 |
| 1073.2 | 2.8 | 4.25 | 5.25 |

Reference: [35]. Due to limited data the experimental values are given.

TABLE 62. $BeF_2$-NaF: Surface tension

Numerical values (dyn $cm^{-1}$)

Mol percent NaF

| $T$ | 63.0 | 57.5 | 57.1 |
|---|---|---|---|
| 780 | 209.6 | 200.5 | 187.6 |
| 800 | 206.3 | 197.8 | 185.3 |
| 820 | 203.0 | 195.1 | 183.0 |
| 840 | 199.7 | 192.4 | 180.7 |
| 860 | 196.4 | 189.6 | 178.3 |
| 880 | 193.1 | 186.9 | 176.0 |
| 900 | 189.8 | 184.2 | 173.7 |
| 920 | 186.5 | 181.5 | 171.4 |
| 940 | 183.2 | 178.8 | 169.1 |
| 960 | 179.9 | 176.0 | 166.7 |
| 980 | 176.6 | 173.3 | 164.4 |
| 1000 | 173.3 | 170.6 | 162.1 |
| 1020 | 170.0 | 167.9 | 159.8 |
| 1040 | 166.7 | 165.2 | 157.5 |
| 1060 | 163.4 | 162.4 | 155.1 |

TABLE 62 b. Temperature-dependent equations

$\gamma = a + bT$ (dyn $cm^{-1}$)

| Comp. (mol % NaF) | $a$ | $b$ |
|---|---|---|
| 57.1 | 278.1 | −0.116 |
| 57.5 | 306.6 | −0.136 |
| 63.0 | 338.3 | −0.165 |

Reference: [72].
Data reported in equation form.

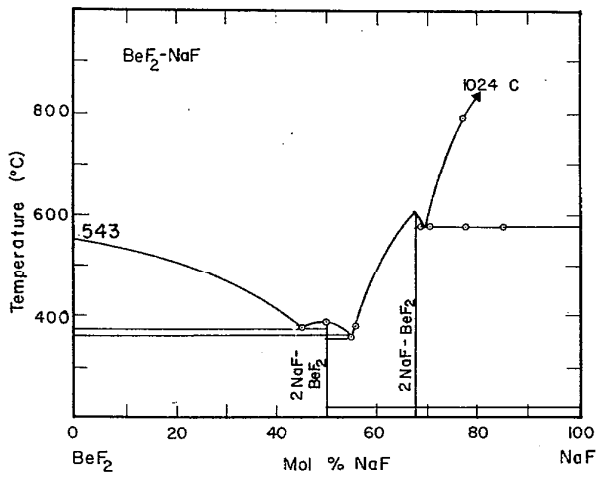


FIGURE 17. Temperature-composition phase diagram for $BeF_2$-NaF. R. E. Thoma, editor, Phase Diagrams for Nuclear Reactor Materials, Oak Ridge National Laboratory, ORNL 2548 (1959).

## $BeF_2$-RbF

### Density

The recommended values in table 65 are based on the work of Cohen et al. (Archimedean method) [35].

TABLE 63 A. Investigations critically re-examined

| Ref. | RbF (mol %) | Temp. range ($T$) |
|---|---|---|
| 35 | 50 | 873–1073 |

### Viscosity

The recommended values in table 66 are based on the work of Cohen et al. (capillary and rotational-cylinder methods) [35].

TABLE 64 A. Investigations critically re-examined

| Ref. | RbF (mol %) | Temp. range ($T$) |
|---|---|---|
| 35 | 50 | 873, 973, 1073 |

Comment: Brief remarks concerning reference [35] are discussed under the system $BeF_2$-NaF.

TABLE 65 a. $BeF_2$-RbF: Density

Numerical values ($gcm^{-3}$)

| $T$ | 50 Mol % RbF |
|---|---|
| 880 | 2.45 |
| 900 | 2.44 |
| 920 | 2.43 |
| 940 | 2.42 |
| 960 | 2.41 |
| 980 | 2.40 |
| 1000 | 2.39 |
| 1020 | 2.38 |
| 1040 | 2.37 |
| 1060 | 2.36 |

TABLE 65 b. Temperature-dependent equation

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % RbF) | $a$ | $b \cdot 10^4$ |
|---|---|---|
| 50 | 2.89 | −5.00 |

Reference: [35]. Data reported in equation form. The temperature range was assumed to be the same as for viscosity measurements.

TABLE 66. $BeF_2$–RbF: Viscosity

Numerical values (cp)

| $T$ | 50 Mol % RbF |
|---|---|
| 873.2 | 11.5 |
| 973.2 | 5.2 |
| 1073.2 | 2.75 |

Reference: [35]. Due to limited data the experimental values are given.

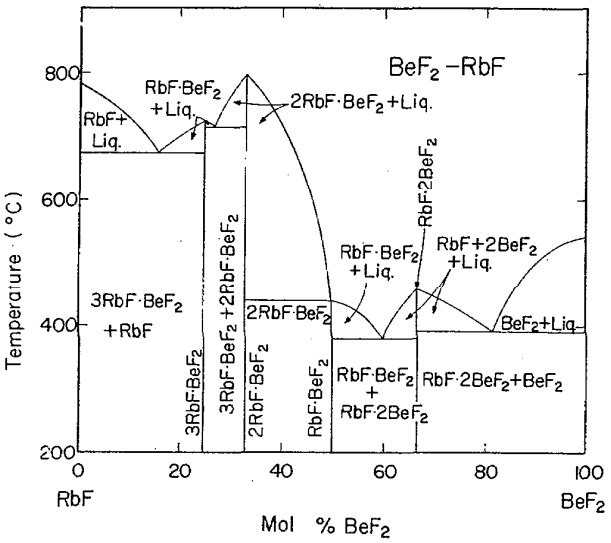


FIGURE 18. Temperature-composition phase diagram for $BeF_2$-RbF. R. E. Moore, C. J. Barton, L. M. Bratcher, T. N. McVay, G. D. White, R. J. Sheil, W. R. Grimes, and R. E. Meadows, Oak Ridge National Laboratory, Phase Diagrams of Nuclear Reactor Materials, R. E. Thoma, ed. ORNL-2548, 39 (1959).

## $BeF_2$-$UF_4$

### Density

The recommended values in table 68 are based on the work of Blanke et al. (Archimedean method) [18].

TABLE 67 A. Investigations critically re-examined

| Ref. | $UF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 18 | 35 | 1073 |

TABLE 67 B. Cell materials and calibration

| Cell material |
|---|
| Pt cylinder and Pt suspension wire, melt contained in an Inconel crucible [18]. |

TABLE 68. $BeF_2$-$UF_4$: Density

Numerical values ($gcm^{-3}$)

| $T$ | 35 Mol % $UF_4$ |
|---|---|
| 1073.2 | 4.502 |

Reference: [18]. The only experimental value is given.

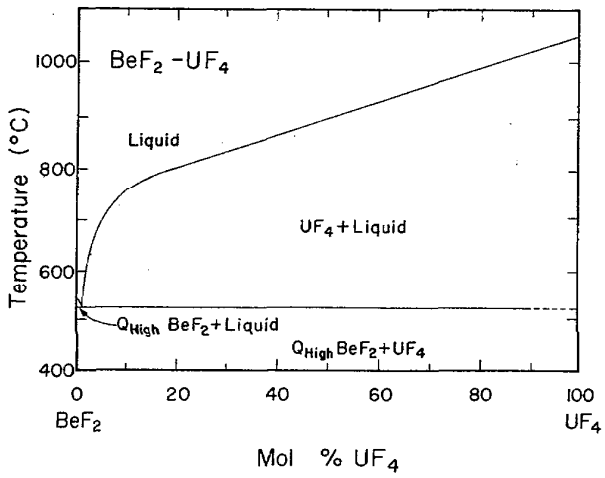


FIGURE 19. Temperature-composition phase diagram for $BeF_2$-$UF_4$. L. V. Jones, D. E. Etter, C. R. Hudgens, A. A. Huffman, T. B. Rhinehammer, N. E. Rogers, P. A. Tuker, and L. J. Wittenberg, J. Amer. Ceram. Soc., 45[2], 79 (1962).

## $CaF_2$-LiF

### Electrical Conductance

The recommended values in table 71 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [87].

TABLE 69 A. Investigations critically re-examined

| Ref. | LiF (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 70, 80, 86, 93, 100 | 1083–1343 |

TABLE 69 B. Comparisons with previous recommendations

| Ref. | Recommended value | | LiF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| 87 | 1 | 2 | 100 | 5.1 | (1150) | 8.2 | (1310) |

TABLE 69 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87]. |

Comment: The specific conductance values measured in reference [87] were reported reproducible to ±1 percent. The precision of the measurements was ±3 percent. The measured resistance was found to be independent of frequency over the range 20 to 20,000 Hz.

## Density

The recommended values in table 72 are based on the work of Porter and Meaker (Archimedean method) [98].

TABLE 70 A. Investigations critically re-examined

| Ref. | LiF (mol %) | Temp. range (T) |
|---|---|---|
| 87 | 70–100 (graphical) | 1273 |
| 98 | 70–100 | 1073–1353 |

TABLE 70 B. Comparisons with previous recommendations

| Ref. | Recommended value | | LiF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | %( min) | (T) | % (max) | (T) |
| 98 | 1 | 2 | 100 | −4.5 | (1310) | −5.6 | (1150) |

TABLE 70 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [87, 98] | Molten KCl [87, 98] |

Comment: Density values for molten KCl, determined by Porter and Meaker [98], agreed with those of Van Artsdalen and Yaffe (Molten Salts: Vol. 1, reference 79) [1] to within a standard deviation of ±0.3 percent.

Experimental density values in reference [98] were fitted to linear equations with standard deviations in the range: $7.00\times10^{-3}$ gcm$^{-3}$ (93 mol % LiF) to $19.0\times10^{-3}$ gcm$^{-3}$ (70 mol % LiF).

## Melt Preparation and Purification

Reagent-grade chemicals were used in references [87] and [98]. After vacuum drying at 400 °C the salts were cooled and combined in the correct proportions. The salts were then placed in graphite crucibles and heated under vacuum (50 μm (Hg) to 600 °C. For density and conductance measurements the mixtures were melted in an atmosphere of helium in a controlled-atmosphere chamber. Melt compositions were confirmed by analyses after density measurements.

TABLE 71 a. $CaF_2$-LiF: Electrical conductance

Specific conductance: Numerical values (ohm$^{-1}$ cm$^{-1}$)

Mol percent LiF

| T | 100.0 | 93.0 | 86.0 | 80.0 | 70.0 |
|---|---|---|---|---|---|
| 1090 | | | 6.39 | 6.60 | |
| 1100 | | | 6.46 | 6.68 | |
| 1110 | | | 6.52 | 6.75 | |
| 1120 | | | 6.59 | 6.83 | |
| 1130 | | 8.20 | 6.66 | 6.90 | |
| 1140 | | 8.25 | 6.72 | 6.98 | |
| 1150 | 9.10 | 8.31 | 6.79 | 7.05 | |
| 1160 | 9.16 | 8.37 | 6.86 | 7.13 | 6.27 |
| 1170 | 9.22 | 8.42 | 6.92 | 7.20 | 6.32 |
| 1180 | 9.27 | 8.48 | 6.99 | 7.28 | 6.38 |
| 1190 | 9.33 | 8.54 | 7.06 | 7.35 | 6.44 |
| 1200 | 9.39 | 8.59 | 7.12 | 7.42 | 6.50 |
| 1210 | 9.45 | 8.65 | 7.19 | 7.50 | 6.55 |
| 1220 | 9.51 | 8.71 | 7.25 | 7.57 | 6.61 |
| 1230 | 9.57 | 8.76 | 7.32 | 7.65 | 6.67 |
| 1240 | 9.62 | 8.82 | 7.39 | 7.72 | 6.72 |
| 1250 | 9.68 | 8.88 | 7.45 | 7.80 | 6.78 |
| 1260 | 9.74 | 8.93 | 7.52 | 7.87 | 6.84 |
| 1270 | 9.80 | 8.99 | 7.59 | 7.95 | 6.90 |
| 1280 | 9.86 | 9.05 | 7.65 | 8.02 | 6.95 |
| 1290 | 9.92 | 9.10 | 7.72 | 8.09 | 7.01 |
| 1300 | 9.97 | 9.16 | 7.79 | 8.17 | 7.07 |
| 1310 | 10.03 | 9.22 | 7.85 | 8.24 | 7.12 |
| 1320 | 10.09 | 9.27 | 7.92 | 8.32 | 7.18 |
| 1330 | 10.15 | 9.33 | 7.98 | 8.39 | 7.24 |
| 1340 | 10.21 | 9.39 | 8.05 | 8.47 | 7.30 |

TABLE 71 b. Temperature-dependent equations

$\kappa = a + bT$ ($ohm^{-1}\ cm^{-1}$)

| Comp. (mol % LiF) | $a \cdot 10^1$ | $b \cdot 10^3$ | Stand. dev. [87] |
|---|---|---|---|
| 70.0 | −3.716 | 5.722 | 0.0470 |
| 80.0 | −15.14 | 7.448 | 0.0478 |
| 86.0 | −0.8412 | 6.636 | 0.0268 |
| 93.0 | 17.86 | 5.673 | 0.0290 |
| 100.0 | 23.95 | 5.830 | 0.0500 |

Reference: [87]. Data reported in equation form.

TABLE 72 a. $CaF_2$-LiF: Density

Numerical values ($gcm^{-3}$)

Mol percent LiF

| $T$ | 100.0 | 93.0 | 86.0 | 80.0 | 70.0 |
|---|---|---|---|---|---|
| 1080 | | | | 2.053 | |
| 1095 | | | 1.937 | 2.047 | |
| 1110 | | | 1.932 | 2.042 | |
| 1125 | 1.700 | 1.825 | 1.926 | 2.036 | |
| 1140 | 1.695 | 1.821 | 1.921 | 2.031 | |
| 1155 | 1.690 | 1.817 | 1.916 | 2.025 | 2.144 |
| 1170 | 1.685 | 1.813 | 1.910 | 2.020 | 2.136 |
| 1185 | 1.680 | 1.809 | 1.905 | 2.014 | 2.127 |
| 1200 | 1.675 | 1.805 | 1.899 | 2.009 | 2.118 |
| 1215 | 1.670 | 1.802 | 1.894 | 2.003 | 2.110 |
| 1230 | 1.666 | 1.798 | 1.888 | 1.997 | 2.101 |
| 1245 | 1.661 | 1.794 | 1.883 | 1.992 | 2.093 |
| 1260 | 1.656 | 1.790 | 1.877 | 1.986 | 2.084 |
| 1275 | 1.651 | 1.786 | 1.872 | 1.981 | 2.075 |
| 1290 | 1.646 | 1.782 | 1.866 | 1.975 | 2.067 |
| 1305 | 1.641 | 1.778 | 1.861 | 1.970 | 2.058 |
| 1320 | 1.636 | 1.774 | 1.856 | 1.964 | 2.049 |
| 1335 | 1.631 | 1.770 | 1.850 | 1.959 | 2.041 |
| 1350 | 1.626 | 1.766 | 1.845 | 1.953 | 2.032 |

TABLE 72 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % LiF) | $a$ | $b \cdot 10^4$ | Stand. dev. [98] |
|---|---|---|---|
| 70.0 | 2.809 | −5.755 | 0.0190 |
| 80.0 | 2.453 | −3.704 | 0.0113 |
| 86.0 | 2.336 | −3.640 | 0.00750 |
| 93.0 | 2.120 | −2.621 | 0.00700 |
| 100.0 | 2.074 | −3.321 | 0.00705 |

Reference: [98]. Data reported in equation form.

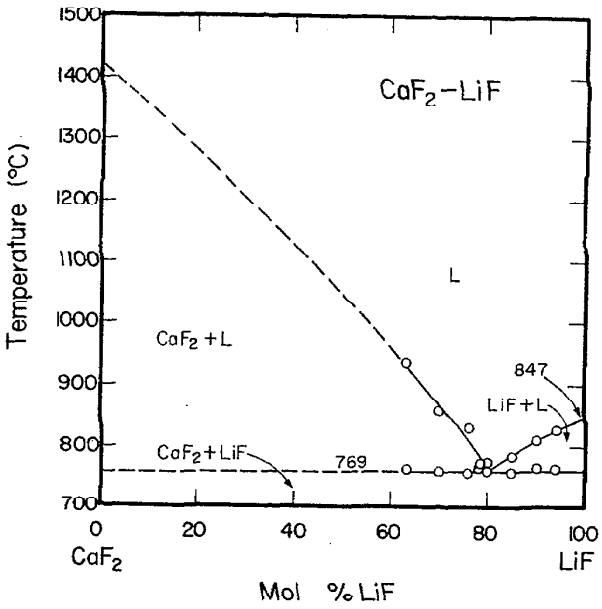


FIGURE 20. Temperature-composition phase diagram for $CaF_2$-LiF. W. E. Roake, J. Electrochem. Soc., **104**, 661 (1957).

## $CaF_2$-NaF

### Electrical Conductance

The recommended values in table 75 are based on the work of Thompson and Kaye (classical ac technique) [111].

TABLE 73 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range ($T$) |
|---|---|---|
| **111** | 48.2 | 1173–1373 |
| 10 | 94.4 | 1253, 1273, 1293 |
| 100* | 48.2 | 1173, 1273, 1373 |

*Data from reference [111].

TABLE 73 B. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) | Calibration |
|---|---|---|---|
| Pt crucible [10, **111**] | Pt [10, **111**] | 1000 [111] | Molten $KNO_3$ [111]<br>0.1 N KCl (25 °C) [10] |

## Density

The recommended values in table 76 are based on the work of Abramov and Kozunov (Archimedean method) [7].

TABLE 74 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range ($T$) |
|---|---|---|
| 7 | 50.0, 66.8, 83.5, 100 | 1143–1443 |

TABLE 74 B. Comparisons with previous recommendations

| Ref. | Recommended value | | NaF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 7 | 1 | 3 | 100 | 0.56 | (1383) | 0.95 | (1283) |

## Melt Preparation and Purification

Thompson and Kaye [111] used analyzed chemical reagents (J. T. Baker Chemical Co.) without further purification.

Sodium fluoride, used by Abramov and Kozunov [7], was purified by sublimation.

TABLE 75 a. $CaF_2$-NaF: Electrical conductance

Specific conductance: Numerical values ($ohm^{-1}\ cm^{-1}$)

| $T$ | 48.2 Mol % NaF |
|---|---|
| 1180 | 4.859 |
| 1200 | 4.960 |
| 1220 | 5.062 |
| 1240 | 5.162 |
| 1260 | 5.264 |
| 1280 | 5.366 |
| 1300 | 5.467 |
| 1320 | 5.568 |
| 1340 | 5.670 |
| 1360 | 5.771 |

TABLE 75 b. Temperature-dependent equation

$\kappa = a + bT$ ($ohm^{-1}\ cm^{-1}$)

| Comp. (mol % NaF) | $a$ | $b \cdot 10^3$ | Stand. error of est. |
|---|---|---|---|
| 48.2 | −1.1188 | 5.0660 | 0.050 |

Reference: [111]. Data reported in numerical form.

TABLE 76 a. $CaF_2$-NaF: Density

Numerical values ($gcm^{-3}$)

| $T$ | Mol percent NaF | | | |
|---|---|---|---|---|
| | 100.0 | 83.5 | 66.8 | 50.0 |
| 1150 | | | 2.299 | |
| 1160 | | | 2.294 | |
| 1170 | | | 2.288 | |
| 1180 | | | 2.283 | |
| 1190 | | | 2.277 | |
| 1200 | | | 2.272 | |
| 1210 | | 2.150 | 2.266 | |
| 1220 | | 2.144 | 2.261 | |
| 1230 | | 2.138 | 2.256 | |
| 1240 | | 2.132 | 2.250 | |
| 1250 | | 2.126 | 2.245 | |
| 1260 | | 2.119 | 2.239 | |
| 1270 | | 2.113 | 2.234 | |
| 1280 | | 2.107 | 2.228 | |
| 1290 | 1.951 | 2.101 | 2.223 | |
| 1300 | 1.944 | 2.095 | 2.217 | |
| 1310 | 1.938 | 2.089 | 2.212 | |
| 1320 | 1.932 | 2.083 | 2.207 | |
| 1330 | 1.926 | 2.077 | 2.201 | 2.357 |
| 1340 | 1.919 | 2.071 | 2.196 | 2.352 |
| 1350 | 1.913 | 2.065 | 2.190 | 2.347 |
| 1360 | 1.907 | 2.059 | 2.185 | 2.341 |
| 1370 | 1.901 | 2.053 | 2.179 | 2.336 |
| 1380 | 1.894 | 2.047 | 2.174 | 2.330 |
| 1390 | 1.888 | 2.041 | 2.168 | 2.325 |
| 1400 | | 2.035 | 2.163 | 2.320 |
| 1410 | | 2.029 | 2.157 | 2.314 |
| 1420 | | 2.023 | 2.152 | 2.309 |
| 1430 | | 2.017 | 2.147 | 2.303 |
| 1440 | | 2.011 | | 2.298 |

TABLE 76 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % NaF) | $a$ | $b \cdot 10^4$ | Stand. error of est. |
|---|---|---|---|
| 50.0 | 3.0783 | −5.4195 | 0.0018 |
| 66.8 | 2.9258 | −5.4489 | 0.0054 |
| 83.5 | 2.8803 | −6.0380 | 0.0043 |
| 100.0 | 2.7571 | −6.2513 | 0.0016 |

Reference: [7]. Data reported in equation form.

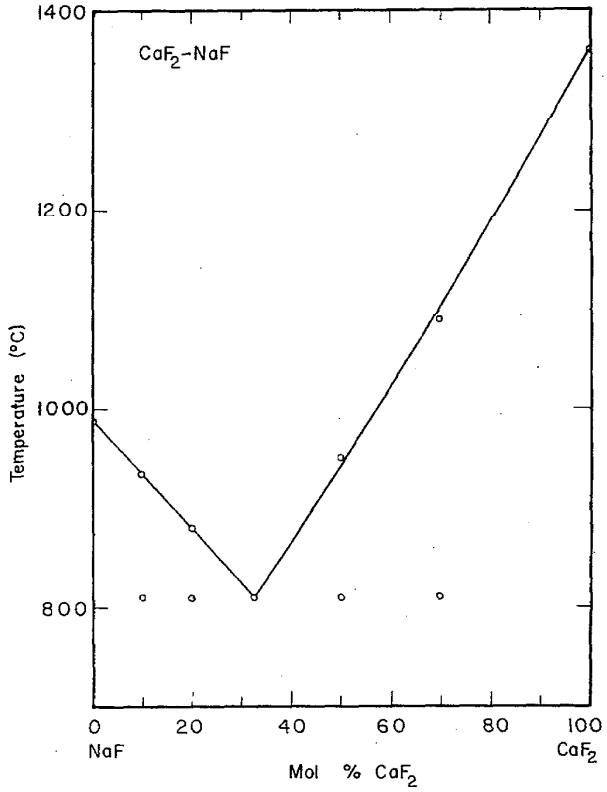


FIGURE 21. Temperature-composition phase diagram for $CaF_2$-NaF. P. P. Fedotyeff and W. P. Ilyinskiy, Z. Anorg. Allg. Chem., **129**, 93 (1923).

## $CeF_3$-KF

### Electrical Conductance

The recommended values in table 79 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [87].

TABLE 77 A. Investigations critically re-examined

| Ref. | KF (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 60, 70, 80, 90, 100 | 1023–1343 |

TABLE 77 B. Comparisons with previous recommendations

| Ref. | Recommended value | | KF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 87 | 1 | 3 | 100 | 3.5 | (1280) | 4.5 | (1140) |

TABLE 77 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

Comment: Brief remarks concerning reference [87] are discussed under the system $CaF_2$-LiF.

### Density

The recommended values in tables 80, 81 are based on the work of Meaker and Porter (Archimedean method) [98].

TABLE 78 A. Investigations critically re-examined

| Ref. | KF (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 60–100 (graphical) | 1273 |
| 98 | 60, 70, 80, 90, 100 | 1043–1353 |

TABLE 78 B. Comparisons with previous recommendations

| Ref. | Recommended value | | KF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| 98 | 1 | 3 | 100 | −3.1 | (1140–1280) | | |

TABLE 78 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [87, 98] | Molten KCl [87, 98] |

Comment: Brief remarks concerning reference [98] are discussed under the system $CaF_2$–LiF.

Density values [98] were reported in the form of linear temperature dependent equations with standard deviations in the range: $2.53\times10^{-3}$ gcm$^{-3}$ (90 mol % KF) to $11.9\times10^{-3}$ gcm$^{-3}$ (70 mol % KF).

## Melt Preparation and Purification

The preparation of pure salts by Porter et al. [87, 98] is described under the system $CaF_2$-LiF. Cerium fluoride contained less than 0.1 weight-percent metallic impurities.

TABLE 79 a. $CeF_3$-KF: Electrical conductance

Specific conductance: Numerical values (ohm$^{-1}$ cm$^{-1}$)

Mol percent KF

| T | 100.0 | 90.0 | 80.0 | 70.0 | 60.0 |
|---|---|---|---|---|---|
| 1030 | | | | 1.36 | |
| 1040 | | | 1.77 | 1.40 | |
| 1050 | | | 1.81 | 1.44 | |
| 1060 | | | 1.84 | 1.47 | |
| 1070 | | | 1.88 | 1.51 | |
| 1080 | | | 1.91 | 1.54 | |
| 1090 | | | 1.95 | 1.58 | |
| 1100 | | | 1.98 | 1.61 | |
| 1110 | | 2.69 | 2.02 | 1.65 | |
| 1120 | | 2.73 | 2.05 | 1.68 | |
| 1130 | | 2.77 | 2.09 | 1.72 | |
| 1140 | 3.74 | 2.81 | 2.13 | 1.75 | |
| 1150 | 3.77 | 2.85 | 2.16 | 1.79 | |
| 1160 | 3.80 | 2.88 | 2.20 | 1.82 | |
| 1170 | 3.83 | 2.92 | 2.23 | 1.86 | 1.70 |
| 1180 | 3.86 | 2.96 | 2.27 | 1.89 | 1.74 |
| 1190 | 3.89 | 3.00 | 2.30 | 1.93 | 1.77 |
| 1200 | 3.92 | 3.04 | 2.34 | 1.96 | 1.81 |
| 1210 | 3.95 | 3.08 | 2.37 | 2.00 | 1.85 |
| 1220 | 3.98 | 3.12 | 2.41 | 2.03 | 1.88 |
| 1230 | 4.01 | 3.15 | 2.44 | 2.07 | 1.92 |
| 1240 | 4.03 | 3.19 | 2.48 | 2.10 | 1.95 |
| 1250 | 4.06 | 3.23 | 2.51 | 2.14 | 1.99 |
| 1260 | 4.09 | 3.27 | 2.55 | 2.17 | 2.03 |
| 1270 | 4.12 | 3.31 | 2.59 | 2.21 | 2.06 |
| 1280 | 4.15 | 3.35 | 2.62 | 2.24 | 2.10 |
| 1290 | 4.18 | 3.39 | 2.66 | 2.28 | 2.13 |
| 1300 | 4.21 | 3.42 | 2.69 | 2.31 | 2.17 |
| 1310 | 4.24 | 3.46 | 2.73 | 2.35 | 2.21 |
| 1320 | 4.27 | 3.50 | 2.76 | 2.38 | 2.24 |
| 1330 | 4.30 | 3.54 | 2.80 | 2.42 | 2.28 |
| 1340 | 4.33 | 3.58 | 2.83 | 2.45 | 2.31 |

TABLE 79 b. Temperature-dependent equations

$\kappa = a + bT$ (ohm$^{-1}$ cm$^{-1}$)

| Comp. (mol % KF) | a | $b\cdot10^3$ | Stand. deviation [87] |
|---|---|---|---|
| 60.0 | −2.498 | 3.590 | 0.0137 |
| 70.0 | −2.256 | 3.515 | 0.0137 |
| 80.0 | −1.911 | 3.540 | 0.0153 |
| 90.0 | −1.594 | 3.860 | 0.0240 |
| 100.0 | 0.388 | 2.940 | 0.0179 |

Reference: [87]. Data reported in equation form.

TABLE 80 a. $CeF_3$-KF: Density

Numerical values ($gcm^{-3}$)

Mol percent KF

| $T$ | 100 | 95 | 90 | 85 | 80 | 75 | 70 | 65 | 60 |
|---|---|---|---|---|---|---|---|---|---|
| 1050 | | | | | 2.595 | 2.759 | 2.925 | | |
| 1065 | | | | 2.418 | 2.583 | 2.748 | 2.913 | | |
| 1080 | | | 2.239 | 2.406 | 2.572 | 2.737 | 2.902 | | |
| 1095 | | | 2.228 | 2.395 | 2.561 | 2.726 | 2.891 | 3.058 | |
| 1110 | | 2.046 | 2.217 | 2.384 | 2.550 | 2.715 | 2.880 | 3.047 | |
| 1125 | | 2.035 | 2.206 | 2.374 | 2.539 | 2.704 | 2.869 | 3.036 | |
| 1140 | 1.849 | 2.024 | 2.195 | 2.363 | 2.529 | 2.694 | 2.859 | 3.025 | |
| 1155 | 1.839 | 2.014 | 2.184 | 2.352 | 2.518 | 2.683 | 2.848 | 3.015 | |
| 1170 | 1.828 | 2.003 | 2.174 | 2.342 | 2.507 | 2.672 | 2.838 | 3.004 | |
| 1185 | 1.818 | 1.993 | 2.163 | 2.331 | 2.497 | 2.662 | 2.827 | 2.994 | 3.162 |
| 1200 | 1.808 | 1.982 | 2.153 | 2.321 | 2.487 | 2.652 | 2.817 | 2.983 | 3.152 |
| 1215 | 1.797 | 1.972 | 2.143 | 2.311 | 2.476 | 2.641 | 2.807 | 2.973 | 3.142 |
| 1230 | 1.787 | 1.962 | 2.133 | 2.300 | 2.466 | 2.631 | 2.796 | 2.963 | 3.132 |
| 1245 | 1.777 | 1.952 | 2.123 | 2.290 | 2.456 | 2.621 | 2.786 | 2.953 | 3.122 |
| 1260 | 1.767 | 1.942 | 2.113 | 2.280 | 2.446 | 2.611 | 2.776 | 2.943 | 3.112 |
| 1275 | 1.757 | 1.932 | 2.103 | 2.271 | 2.436 | 2.601 | 2.767 | 2.933 | 3.102 |
| 1290 | 1.748 | 1.922 | 2.093 | 2.261 | 2.427 | 2.592 | 2.757 | 2.923 | 3.092 |
| 1305 | 1.738 | 1.913 | 2.084 | 2.251 | 2.417 | 2.582 | 2.747 | 2.914 | 3.082 |
| 1320 | 1.728 | 1.903 | 2.074 | 2.242 | 2.408 | 2.572 | 2.738 | 2.904 | 3.073 |
| 1335 | 1.719 | 1.894 | 2.065 | 2.232 | 2.398 | 2.563 | 2.728 | 2.895 | 3.063 |
| 1350 | 1.710 | 1.884 | 2.055 | 2.223 | 2.389 | 2.554 | 2.719 | 2.885 | 3.054 |

TABLE 80 b. Two-dimensional equation and statistical parameters

$\rho = a + bT + cC + dT^2 + eC^2 + fC^3$ ($gcm^{-3}$)

| $a$ | $b \cdot 10^3$ | $c \cdot 10^2$ | $d \cdot 10^7$ | $e \cdot 10^4$ | $f \cdot 10^6$ | Max. percent departure | Stand. error of est. |
|---|---|---|---|---|---|---|---|
| 2.94846 | −1.21553 | 3.54550 | 2.20620 | −1.03800 | 1.44443 | 0.36 (1133.2K, 0 mol % $CeF_3$) | 0.004 |

Reference: [98]. Data reported in numerical form.
$C$ = mol % $CeF_3$.

TABLE 81 a. $CeF_3$-KF: Density

Numerical values ($gcm^{-3}$)

Mol percent KF

| | 100.0 | 90.0 | 80.0 | 70.00 | 60.0 |
|---|---|---|---|---|---|
| 1050 | | | 2.593 | 2.927 | |
| 1065 | | | 2.582 | 2.916 | |
| 1080 | | 2.236 | 2.571 | 2.906 | |
| 1095 | | 2.226 | 2.561 | 2.895 | |
| 1110 | | 2.216 | 2.550 | 2.884 | |
| 1125 | | 2.206 | 2.540 | 2.873 | |
| 1140 | 1.844 | 2.196 | 2.529 | 2.863 | |
| 1155 | 1.834 | 2.186 | 2.518 | 2.852 | |
| 1170 | 1.825 | 2.176 | 2.508 | 2.841 | |
| 1185 | 1.815 | 2.166 | 2.497 | 2.830 | 3.154 |
| 1200 | 1.806 | 2.156 | 2.487 | 2.819 | 3.146 |
| 1215 | 1.797 | 2.146 | 2.476 | 2.809 | 3.138 |
| 1230 | 1.787 | 2.136 | 2.466 | 2.798 | 3.129 |
| 1245 | 1.778 | 2.126 | 2.455 | 2.787 | 3.121 |
| 1260 | 1.769 | 2.116 | 2.444 | 2.776 | 3.112 |
| 1275 | 1.759 | 2.106 | 2.434 | 2.766 | 3.104 |
| 1290 | 1.750 | 2.096 | 2.423 | 2.755 | 3.095 |
| 1305 | 1.741 | 2.086 | 2.413 | 2.744 | 3.087 |
| 1320 | 1.731 | 2.076 | 2.402 | 2.733 | 3.079 |
| 1335 | 1.722 | 2.065 | 2.392 | 2.723 | 3.070 |
| 1350 | 1.712 | 2.055 | 2.381 | 2.712 | 3.062 |

TABLE 81 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % KF) | $a$ | $b \cdot 10^4$ | Stand. dev. [98] |
|---|---|---|---|
| 60.0 | 3.820 | −5.617 | 0.00985 |
| 70.0 | 3.680 | −7.171 | 0.0119 |
| 80.0 | 3.333 | −7.052 | 0.00376 |
| 90.0 | 2.957 | −6.678 | 0.00253 |
| 100.0 | 2.555 | −6.241 | 0.00276 |

Reference: [98]. Data reported in equation form.

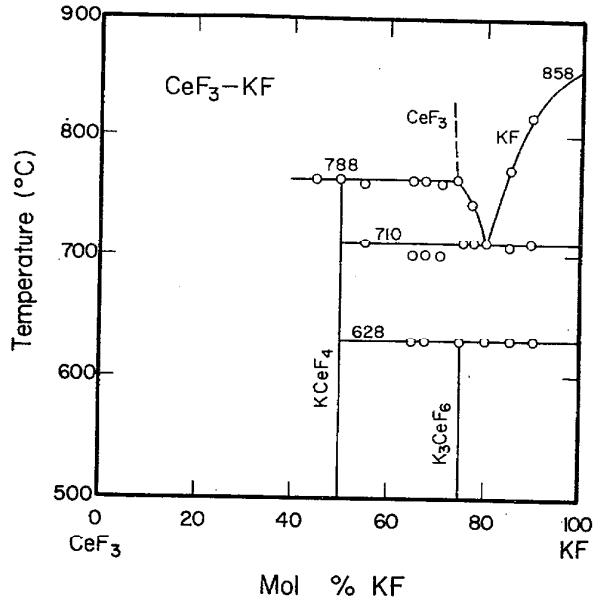


FIGURE 22. Temperature-composition phase diagram for $CeF_3$-KF. G. A. Bukhalova and E. P. Babaeva, Russ. J. Inorg. Chem., **11**, 337 (1966).

## $CeF_3$-LiF

### Electrical Conductance

The recommended values in table 84 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [87].

TABLE 82 A. Investigations critically re-examined

| Ref. | LiF (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 70, 76, 81, 88, 100 | 1083–1343 |

TABLE 82 B. Comparisons with previous recommendations

| Ref. | Recommended value | | LiF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 87 | 1 | 2 | 100 | 5.1 | (1150) | 8.2 | (1310) |

TABLE 82 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

Comment: Brief remarks concerning reference [87] are discussed under the system $CaF_2$–LiF.

## Density

The recommended values in tables 85, 86 are based on the work of Meaker and Porter (Archimedean method) [98].

TABLE 83 A. Investigations critically re-examined

| Ref. | LiF (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 70–100 (graphical) | 1273 |
| 98 | 70, 76, 81, 88, 100 | 1083–1353 |

TABLE 83 B. Comparisons with previous recommendations

| Ref. | Recommended value | | LiF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 98 | 1 | 2 | 100 | −4.5 | (1310) | −5.6 | (1150) |

TABLE 83 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [87, 98] | Molten KCl [87, 98] |

Comment: Brief remarks concerning reference [98] are discussed under the system $CaF_2$–LiF.

Density values [98] were reported in the form of linear temperature-dependent equations with standard deviations in the range: $1.94\times10^{-2}$ gcm$^{-3}$ (76 mol % LiF) to $19.9\times10^{-3}$ gcm$^{-3}$ (88 mol % LiF).

### Melt Preparation and Purification

The preparation of pure salts by Porter et al. [87, 98] is described under the system $CaF_2$-LiF. Cerium fluoride contained less than 0.1 weight-percent metallic impurities.

TABLE 84 a. $CeF_3$–LiF: Electrical conductance

Specific conductance: Numerical values (ohm$^{-1}$ cm$^{-1}$)

| $T$ | Mol percent LiF | | | | |
|---|---|---|---|---|---|
| | 100.0 | 88.0 | 81.0 | 76.0 | 70.0 |
| 1090 | | | 5.42 | | |
| 1100 | | | 5.49 | | |
| 1110 | | | 5.55 | | |
| 1120 | | 6.72 | 5.61 | | |
| 1130 | | 6.79 | 5.68 | | |
| 1140 | | 6.85 | 5.74 | | |
| 1150 | 9.10 | 6.91 | 5.81 | | |
| 1160 | 9.16 | 6.98 | 5.87 | | |
| 1170 | 9.22 | 7.04 | 5.93 | | |
| 1180 | 9.27 | 7.11 | 6.00 | | |
| 1190 | 9.33 | 7.17 | 6.06 | 5.51 | |
| 1200 | 9.39 | 7.23 | 6.12 | 5.57 | |
| 1210 | 9.45 | 7.30 | 6.19 | 5.64 | |
| 1220 | 9.51 | 7.36 | 6.25 | 5.70 | |
| 1230 | 9.57 | 7.43 | 6.32 | 6.76 | 5.46 |
| 1240 | 9.62 | 7.49 | 6.38 | 5.83 | 5.52 |
| 1250 | 9.68 | 7.55 | 6.44 | 5.89 | 5.58 |
| 1260 | 9.74 | 7.62 | 6.51 | 5.96 | 5.64 |
| 1270 | 9.80 | 7.68 | 6.57 | 6.02 | 5.69 |
| 1280 | 9.86 | 7.75 | 6.64 | 6.08 | 5.75 |
| 1290 | 9.92 | 7.81 | 6.70 | 6.15 | 5.81 |
| 1300 | 9.97 | 7.88 | 6.76 | 6.21 | 5.87 |
| 1310 | 10.3 | 7.94 | 6.83 | 6.27 | 5.93 |
| 1320 | 10.09 | 8.00 | 6.89 | 6.34 | 5.99 |
| 1330 | 10.15 | 8.07 | 6.95 | 6.40 | 6.05 |
| 1340 | 10.21 | 8.13 | 7.02 | 6.46 | 6.11 |

TABLE 84 b. Temperature-dependent equations

$\kappa = a + bT$ (ohm$^{-1}$ cm$^{-1}$)

| Comp. (mol % LiF) | $a$ | $b\cdot10^3$ | Stand. deviation [87] |
|---|---|---|---|
| 70.0 | −1.782 | 5.887 | 0.0399 |
| 76.0 | −2.040 | 6.345 | 0.0180 |
| 81.0 | −1.533 | 6.381 | 0.0495 |
| 88.0 | −0.452 | 6.405 | 0.0464 |
| 100.0 | 2.395 | 5.830 | 0.0500 |

Reference: [87]. Data reported in equation form.

TABLE 85 a. $CeF_3$-LiF: Density

Numerical values ($gcm^{-3}$)

Mol percent LiF

| $T$ | 100 | 95 | 90 | 85 | 80 | 75 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|
| 1090 | | | | 2.811 | | | | |
| 1105 | | | 2.447 | 2.802 | 3.116 | | | 3.116 |
| 1120 | | | 2.438 | 2.792 | 3.105 | | | 3.105 |
| 1135 | 1.701 | | 2.429 | 2.782 | 3.095 | | | 3.095 |
| 1150 | 1.695 | | 2.420 | 2.773 | 3.085 | | | 3.085 |
| 1165 | 1.690 | 2.046 | 2.412 | 2.763 | 3.074 | 3.322 | | 3.074 |
| 1180 | 1.684 | 2.039 | 2.403 | 2.753 | 3.064 | 3.312 | | 3.064 |
| 1195 | 1.679 | 2.031 | 2.394 | 2.743 | 3.054 | 3.301 | 3.461 | 3.054 |
| 1210 | 1.674 | 2.024 | 2.386 | 2.734 | 3.044 | 3.291 | 3.450 | 3.044 |
| 1225 | 1.668 | 2.017 | 2.377 | 2.724 | 3.033 | 3.280 | 3.440 | 3.033 |
| 1240 | 1.663 | 2.009 | 2.368 | 2.714 | 3.023 | 3.270 | 3.430 | 3.023 |
| 1255 | 1.657 | 2.002 | 2.359 | 2.705 | 3.013 | 3.260 | 3.420 | 3.013 |
| 1270 | 1.652 | 1.995 | 2.351 | 2.695 | 3.003 | 3.249 | 3.410 | 3.003 |
| 1285 | 1.647 | 1.988 | 2.342 | 2.685 | 2.992 | 3.239 | 3.400 | 2.992 |
| 1300 | 1.641 | 1.980 | 2.333 | 2.675 | 2.982 | 3.229 | 3.390 | 2.982 |
| 1315 | 1.636 | 1.973 | 2.324 | 2.666 | 2.972 | 3.218 | 3.380 | 2.972 |
| 1330 | 1.630 | 1.966 | 2.316 | 2.656 | 2.961 | 3.208 | 3.370 | 2.961 |
| 1345 | 1.625 | 1.958 | 2.307 | 2.646 | 2.951 | 3.197 | 3.360 | 2.951 |

TABLE 85 b. Two-dimensional equation and statistical parameters

$\rho = a + bT + cC + dC^3 + eTC + fTC^2$ ($gcm^{-3}$)

| $a$ | $b \cdot 10^4$ | $c \cdot 10^1$ | $d \cdot 10^5$ | $e \cdot 10^5$ | $f \cdot 10^7$ | Max. percent departure | Stand. error of est. |
|---|---|---|---|---|---|---|---|
| 2.10920 | −3.60006 | 1.01307 | −3.28974 | −2.80956 | 5.92992 | 0.38 (1193.2 K 30 Mol % $CeF_3$) | 0.006 |

Reference: [98]. Data reported in equation form.
$C$=mol percent $CeF_3$.

TABLE 86 a. $CeF_3$–LiF: Density

Numerical values ($gcm^{-3}$)

Mol percent LiF

| $T$ | 100.0 | 88.0 | 81.0 | 76.0 | 70.0 |
|---|---|---|---|---|---|
| 1095 | | 2.603 | 3.061 | | |
| 1110 | | 2.594 | 3.050 | | |
| 1125 | 1.700 | 2.585 | 3.039 | | |
| 1140 | 1.695 | 2.575 | 3.029 | | |
| 1155 | 1.690 | 2.566 | 3.018 | 3.297 | |
| 1170 | 1.685 | 2.557 | 3.007 | 3.285 | |
| 1185 | 1.680 | 2.547 | 2.997 | 3.274 | |
| 1200 | 1.675 | 2.538 | 2.986 | 3.263 | 3.445 |
| 1215 | 1.670 | 2.528 | 2.975 | 3.252 | 3.437 |
| 1230 | 1.666 | 2.519 | 2.965 | 3.240 | 3.430 |
| 1245 | 1.661 | 2.510 | 2.954 | 3.229 | 3.422 |
| 1260 | 1.656 | 2.500 | 2.944 | 3.218 | 3.414 |
| 1275 | 1.651 | 2.491 | 2.933 | 3.207 | 3.407 |
| 1290 | 1.646 | 2.482 | 2.922 | 3.196 | 3.399 |
| 1305 | 1.641 | 2.472 | 2.912 | 3.184 | 3.391 |
| 1320 | 1.636 | 2.463 | 2.901 | 3.173 | 3.383 |
| 1335 | 1.631 | 2.454 | 2.890 | 3.162 | 3.376 |
| 1350 | 1.626 | 2.444 | 2.880 | 3.151 | 3.368 |

TABLE 86 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % LiF) | $a$ | $b \cdot 10^4$ | Stand. dev. [98] |
|---|---|---|---|
| 70.0 | 4.061 | −5.133 | 0.0094 |
| 76.0 | 4.161 | −7.484 | 0.00194 |
| 81.0 | 3.837 | −7.091 | 0.0140 |
| 88.0 | 3.286 | −6.235 | 0.0199 |
| 100.0 | 2.074 | −3.321 | 0.00705 |

Reference: [98]. Data reported in equation form.

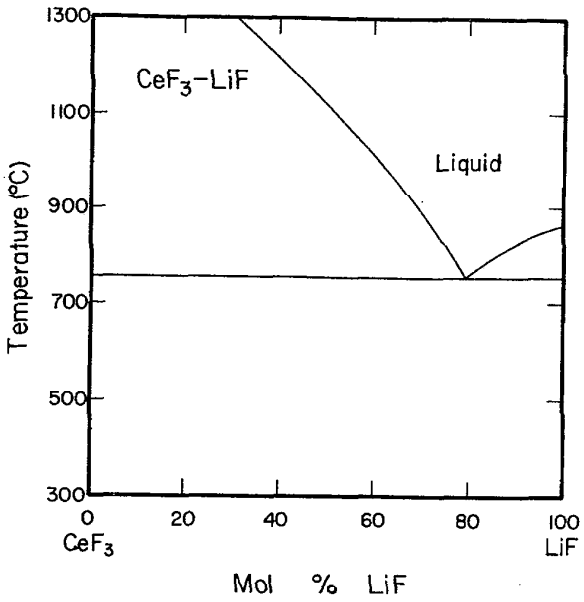


FIGURE 23. Temperature-composition phase diagram for $CeF_3$-LiF. R. E. Thoma, Progress in Science and Technology of the Rare Earths, Vol. 2, p. 110, Pergamon Press, N.Y. 1966.

## $CeF_3$-NaF

### Electrical Conductance

The recommended values in table 89 are based on the work of Meaker, Porter and Kesterke (classical ac technique) [87].

TABLE 87 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 60, 70, 80, 90, 100 | 1093–1343 |

TABLE 87 B. Comparisons with previous recommendations

| Ref. | Recommended value | | NaF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| 87 | 1 | 3 | 0 | 5.0 | (1300) | 7.4 | (1340) |

TABLE 87 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

Comment: Brief remarks concerning reference [87] are discussed under the system $CaF_2$-LiF.

## Density

The recommended values in tables 90, 91 are based on the work of Meaker and Porter (Archimedean method) [98].

TABLE 88 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range (T) |
|---|---|---|
| 87 | 60–100 (graphical) | 1273 |
| 98 | 60, 70, 80, 90, 100 | 1073–1353 |

TABLE 88 B. Comparisons with previous recommendations

| Ref. | Recommended value | | NaF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| 98 | 1 | 3 | 0 | −2.2 | (1270) | −2.5 | (1350) |

TABLE 88 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [87, 98] | Molten KCl [87, 98] |

Comment: Brief remarks concerning reference [98] are discussed under the system $CaF_2$-LiF.

Density values [98] were reported in the form of linear temperature-dependent equations with standard deviations in the range: $2.39\times10^{-3}$ gcm$^{-3}$ (100 mol % NaF) to $9.40\times10^{-3}$ gcm$^{-3}$ (60 mol % NaF).

## Melt Preparation and Purification

The preparation of pure salts by Porter et al. [87, 98] is described under the system $CaF_2$-LiF. Cerium fluoride contained less than 0.1 weight-percent metallic impurities.

TABLE 89 a. $CeF_3$–NaF: Electrical conductance

Specific conductance: Numerical values (ohm$^{-1}$ cm$^{-1}$)

| T | Mol percent NaF | | | | |
|---|---|---|---|---|---|
| | 100.0 | 90.0 | 80.0 | 70.0 | 60.0 |
| 1100 | | | | 2.48 | |
| 1110 | | | | 2.53 | |
| 1120 | | | 3.08 | 2.58 | |
| 1130 | | | 3.12 | 2.63 | |
| 1140 | | | 3.17 | 2.68 | 2.46 |
| 1150 | | | 3.22 | 2.73 | 2.51 |
| 1160 | | | 3.27 | 2.79 | 2.56 |
| 1170 | | | 3.32 | 2.84 | 2.61 |
| 1180 | | | 3.37 | 2.89 | 2.66 |
| 1190 | | | 3.42 | 2.94 | 2.72 |
| 1200 | | | 3.47 | 2.99 | 2.77 |
| 1210 | | | 3.51 | 3.04 | 2.82 |
| 1220 | | | 3.56 | 3.09 | 2.87 |
| 1230 | | | 3.61 | 3.14 | 2.92 |
| 1240 | | | 3.66 | 3.19 | 2.98 |
| 1250 | | 4.28 | 3.71 | 3.24 | 3.03 |
| 1260 | | 4.31 | 3.76 | 3.29 | 3.08 |
| 1270 | | 4.35 | 3.81 | 3.34 | 3.13 |
| 1280 | | 4.39 | 3.85 | 3.39 | 3.18 |
| 1290 | | 4.43 | 3.90 | 3.44 | 3.24 |
| 1300 | | 4.46 | 3.95 | 3.49 | 3.29 |
| 1310 | 5.33 | 4.50 | 4.00 | 3.55 | 3.34 |
| 1320 | 5.39 | 4.54 | 4.05 | 3.60 | 3.39 |
| 1330 | 5.44 | 4.58 | 4.10 | 3.65 | 3.44 |
| 1340 | 5.50 | 4.61 | 4.15 | 3.70 | 3.50 |

TABLE 89 b. Temperature-dependent equations

$\kappa = a + bT$ (ohm$^{-1}$ cm$^{-1}$)

| Comp. (mol % NaF) | $a$ | $b \cdot 10^3$ | Stand. deviation [87] |
|---|---|---|---|
| 60.0 | −3.474 | 5.201 | 0.0154 |
| 70.0 | −3.088 | 5.063 | 0.0155 |
| 80.0 | −2.377 | 4.868 | 0.0235 |
| 90.0 | −0.394 | 3.736 | 0.0985 |
| 100.0 | −2.060 | 5.640 | 0.0660 |

Reference: [87]. Data reported in equation form.

TABLE 90 a. $CeF_3$-NaF: Density

Numerical values (gcm$^{-3}$)

Mol percent NaF

| $T$ | 100 | 95 | 90 | 85 | 80 | 75 | 70 | 65 | 60 | 72 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1080 | | | | | | 3.178 | 3.370 | | | 3.295 |
| 1095 | | | | | | 3.168 | 3.360 | | | 3.286 |
| 1110 | | | | | 2.951 | 3.159 | 3.351 | 3.525 | | 3.276 |
| 1125 | | | | | 2.942 | 3.149 | 3.341 | 3.515 | | 3.266 |
| 1140 | | | | | 2.932 | 3.139 | 3.331 | 3.504 | | 3.256 |
| 1155 | | | | 2.702 | 2.923 | 3.130 | 3.321 | 3.494 | | 3.247 |
| 1170 | | | | 2.693 | 2.913 | 3.120 | 3.311 | 3.484 | | 3.237 |
| 1185 | | | | 2.683 | 2.904 | 3.111 | 3.301 | 3.474 | 3.627 | 3.227 |
| 1200 | | | | 2.674 | 2.895 | 3.101 | 3.291 | 3.464 | 3.616 | 3.217 |
| 1215 | | | 2.432 | 2.665 | 2.885 | 3.091 | 3.281 | 3.453 | 3.605 | 3.207 |
| 1230 | | | 2.423 | 2.655 | 2.876 | 3.082 | 3.272 | 3.443 | 3.595 | 3.198 |
| 1245 | | | 2.413 | 2.646 | 2.866 | 3.072 | 3.262 | 3.433 | 3.584 | 3.188 |
| 1260 | | | 2.404 | 2.637 | 2.857 | 3.063 | 3.252 | 3.423 | 3.573 | 3.178 |
| 1275 | 1.899 | 2.151 | 2.395 | 2.627 | 2.847 | 3.053 | 3.242 | 2.412 | 2.563 | 2.168 |
| 1290 | 1.890 | 2.142 | 2.385 | 2.618 | 2.838 | 3.043 | 3.232 | 3.402 | 3.552 | 3.159 |
| 1305 | 1.880 | 2.133 | 2.376 | 2.609 | 2.829 | 3.034 | 3.222 | 3.392 | 3.541 | 3.149 |
| 1320 | 1.871 | 2.123 | 2.367 | 2.599 | 2.819 | 3.024 | 3.212 | 3.382 | 3.531 | 3.139 |
| 1335 | 1.861 | 2.114 | 2.358 | 2.590 | 2.810 | 3.014 | 3.202 | 3.372 | 3.520 | 3.129 |
| 1350 | 1.852 | 2.105 | 2.348 | 2.581 | 2.800 | 3.005 | 3.192 | 3.361 | 3.509 | 3.120 |

TABLE 90 b. Two-dimensional equation and statistical parameters

$\rho = a + bT + cC + dC^3 + eTC + fTC^2$ (gcm$^{-3}$)

| $a$ | $b \cdot 10^4$ | $c \cdot 10^2$ | $d \cdot 10^6$ | $e \cdot 10^6$ | $f \cdot 10^7$ | Max. percent departure | Stand. error of est. |
|---|---|---|---|---|---|---|---|
| 2.70452 | −6.31498 | 4.82510 | −2.60170 | 2.26641 | −1.05829 | 0.17 (1343.2K, 20 mol % CeF) | 0.003 |

Reference: [98]. Data reported in equation form.
$C$ = mol percent $CeF_3$.

TABLE 91 a. $CeF_3$–NaF: Density

Numerical values ($gcm^{-3}$)

Mol percent NaF

| $T$ | 100.0 | 90.0 | 80.0 | 70.0 | 60.0 |
|---|---|---|---|---|---|
| 1080 | | | | 3.370 | |
| 1095 | | | | 3.360 | |
| 1110 | | | 2.951 | 3.350 | |
| 1125 | | | 2.941 | 3.341 | |
| 1140 | | | 2.932 | 3.331 | |
| 1155 | | | 2.922 | 3.321 | |
| 1170 | | | 2.912 | 3.312 | |
| 1185 | | | 2.902 | 3.302 | 3.627 |
| 1200 | | | 2.893 | 3.293 | 3.616 |
| 1215 | | 2.435 | 2.883 | 3.283 | 3.605 |
| 1230 | | 2.426 | 2.873 | 3.273 | 3.594 |
| 1245 | | 2.416 | 2.863 | 3.264 | 3.583 |
| 1260 | | 2.407 | 2.854 | 3.254 | 3.573 |
| 1275 | 1.898 | 2.397 | 2.844 | 3.244 | 3.562 |
| 1290 | 1.889 | 2.388 | 2.834 | 3.235 | 3.551 |
| 1305 | 1.879 | 2.378 | 2.825 | 3.225 | 3.540 |
| 1320 | 1.870 | 2.369 | 2.815 | 3.216 | 3.529 |
| 1335 | 1.861 | 2.359 | 2.805 | 3.206 | 3.518 |
| 1350 | 1.852 | 2.350 | 2.795 | 3.196 | 3.507 |

TABLE 91 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % NaF) | $a$ | $b \cdot 10^4$ | Stand. dev. [98] |
|---|---|---|---|
| 60.0 | 4.486 | −7.249 | 0.00940 |
| 70.0 | 4.063 | −6.420 | 0.00907 |
| 80.0 | 3.670 | −6.478 | 0.00798 |
| 90.0 | 3.207 | −6.350 | 0.00353 |
| 100.0 | 2.682 | −6.151 | 0.00239 |

Reference: [98]. Data reported in equation form.

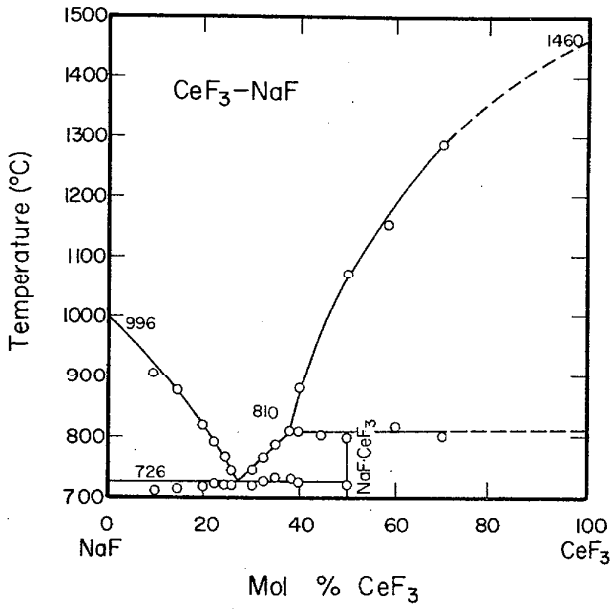


FIGURE 24. Temperature-composition phase diagram for $CeF_3$-NaF. C. J. Barton, J. D. Redman, and R. A. Strehlow, J. Inorg. Nucl. Chem., **20**, 45 (1961).

## $KF\text{-}KBF_4$

### Electrical Conductance

The recommended values in table 93 are based on the work of Selivanov and Stender (classical ac technique) [**125**].

TABLE 92 A. Investigations critically re-examined

| Ref. | $KBF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| **125** | 16.5–80.6 | 723–1073 |

TABLE 92 B. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) | Calibration |
|---|---|---|---|
| Corundum crucible [125] | Pt [125] | 5000 [125] | Melt containing 62% $CaCl_2$—38% NaCl and molten $Na_2B_4O_7$ [125] |

TABLE 93. $KF-KBF_4$: Electrical conductance

Specific conductance: Numerical values ($ohm^{-1}$ $cm^{-1}$)

Mol percent $KBF_4$

| $T$ | 80.6 | 64.9 | 51.8 | 40.9 | 31.6 | 23.5 | 16.5 |
|---|---|---|---|---|---|---|---|
| 723.2 | 0.281 | 0.519 | 0.201 | | | | |
| 773.2 | 0.445 | 0.815 | 0.355 | | | | |
| 823.2 | 0.915 | 1.215 | 0.555 | | | | |
| 873.2 | 1.459 | 2.225 | 1.209 | | | | |
| 923.2 | 3.601 | 4.209 | 3.150 | 2.255 | | | |
| 973.2 | 6.801 | 7.292 | 6.806 | 5.303 | 3.291 | | |
| 1023.2 | 9.807 | 10.015 | 9.345 | 8.406 | 7.105 | 3.902 | |
| 1073.2 | 12.703 | 13.015 | 12.501 | 11.495 | 9.912 | 8.101 | 5.001 |

Reference: [125]. The statistical analysis was unsuccessful therefore the original data are reported.

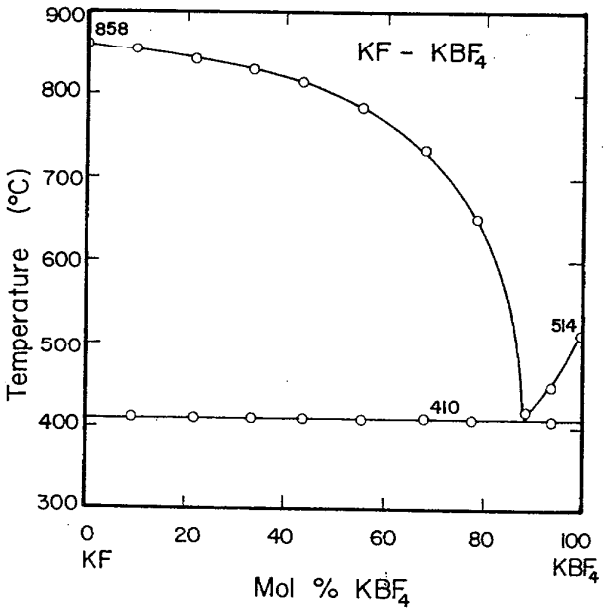


FIGURE 25. Temperature-composition phase diagram for $KF-KBF_4$. V. G. Selivanov and V. V. Stender, Zhur. Neorg. Khim., 4, 2058 (1959); Russ. J. Inorg. Chem., 4 [9], 934 (1959).

## $KF-LaF_3$

### Electrical Conductance

The recommended values in table 96 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [87].

TABLE 94 A. Investigations critically re-examined

| Ref. | $LaF_3$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0, 10.0, 20.0, 30.0, 40.0 | 1043–1343 |

TABLE 94 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $LaF_3$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 87 | 1 | 3 | 0 | 3.5 | (1280) | 4.5 | (1140) |

TABLE 94 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

Comment: Brief remarks concerning reference [87] are discussed under the system $CaF_2$-LiF.

### Density

The recommended values in tables 97, 98 are based on the work of Meaker and Porter (Archimedean method) [98].

TABLE 95 A. Investigations critically re-examined

| Ref. | $LaF_3$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 60–100 (graphical) | 1273 |
| 98 | 0.0, 10.0, 20.0, 30.0, 40.0 | 1043–1353 |

TABLE 95 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $LaF_3$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| 98 | 1 | 3 | 0 | −3.1 | (1140–1280) | | |

Comment: Brief remarks concerning reference [98] are given under the system $CaF_2$–LiF.

Density values [98] were reported in the form of linear temperature-dependent equations with standard deviations in the range: $2.76\times10^{-3}$ gcm$^{-3}$ (0 mol % $LaF_3$) to $5.95\times10^{-3}$ gcm$^{-3}$ (30 mol % $LaF_3$).

## Melt Preparation and Purification

The method of salt purification used by Porter et al. [87, 98] is described under the system $CaF_2$-LiF.

Lanthanum fluoride contained less than 0.1 weight-percent of metallic impurities.

TABLE 96 a. KF-$LaF_3$: Electrical conductance

Specific conductance: Numerical values (ohm$^{-1}$ cm$^{-1}$)

| T | 40.0 | 30.0 | 20.0 | 10.0 | 0.0 |
|---|---|---|---|---|---|
| 1050 | | 1.45 | | | |
| 1060 | | 1.49 | | | |
| 1070 | | 1.53 | | | |
| 1080 | | 1.56 | 1.93 | 2.59 | |
| 1090 | | 1.60 | 1.97 | 2.62 | |
| 1100 | | 1.64 | 2.01 | 2.66 | |
| 1110 | | 1.68 | 2.04 | 2.69 | |
| 1120 | | 1.72 | 2.08 | 2.73 | |
| 1130 | | 1.75 | 2.12 | 2.76 | |
| 1140 | | 1.79 | 2.15 | 2.79 | 3.74 |
| 1150 | | 1.83 | 2.19 | 2.83 | 3.77 |
| 1160 | | 1.87 | 2.23 | 2.86 | 3.80 |
| 1170 | | 1.90 | 2.26 | 2.89 | 3.83 |
| 1180 | | 1.94 | 2.30 | 2.93 | 3.86 |
| 1190 | | 1.98 | 2.34 | 2.96 | 3.89 |
| 1200 | 1.89 | 2.02 | 2.37 | 2.99 | 3.92 |
| 1210 | 1.93 | 2.05 | 2.41 | 3.03 | 3.95 |
| 1220 | 1.97 | 2.09 | 2.45 | 3.06 | 3.98 |
| 1230 | 2.01 | 2.13 | 2.48 | 3.10 | 4.51 |
| 1240 | 2.05 | 2.17 | 2.52 | 3.13 | 4.03 |
| 1250 | 2.09 | 2.21 | 2.56 | 3.16 | 4.06 |
| 1260 | 2.13 | 2.24 | 2.60 | 3.20 | 4.09 |
| 1270 | 2.17 | 2.28 | 2.63 | 3.23 | 4.12 |
| 1280 | 2.21 | 2.32 | 2.67 | 3.26 | 4.15 |
| 1290 | 2.25 | 2.36 | 2.71 | 3.30 | 4.18 |
| 1300 | 2.29 | 2.39 | 2.74 | 3.33 | 4.21 |
| 1310 | 2.32 | 2.43 | 2.78 | 3.36 | 4.24 |
| 1320 | 2.36 | 2.47 | 2.82 | 3.40 | 4.27 |
| 1330 | 2.40 | 2.51 | 2.85 | 3.43 | 4.30 |
| 1340 | 2.44 | 2.55 | 2.89 | 3.46 | 4.33 |

TABLE 96 b. Temperature-dependent equations

$\kappa = a + bT$ (ohm$^{-1}$ cm$^{-1}$)

| Comp. (mol % $LaF_3$) | a | $b\cdot10^3$ | Stand. deviation [87] |
|---|---|---|---|
| 0.0 | 0.388 | 2.940 | 0.0179 |
| 10.0 | −1.037 | 3.359 | 0.0147 |
| 20.0 | −2.046 | 3.683 | 0.0189 |
| 30.0 | −2.511 | 3.773 | 0.0069 |
| 40.2 | −2.807 | 3.917 | 0.0087 |

Reference: [87]. Data reported in equation form.

TABLE 97 a. $KF\text{-}LaF_3$: Density

Numerical values ($gcm^{-3}$)

Mol percent $LaF_3$

| $T$ | 40 | 35 | 30 | 25 | 20 | 15 | 10 | 5 | 0 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1050 | | | | 2.764 | 2.595 | | | | | 2.663 |
| 1065 | | | | 2.752 | 2.584 | 2.413 | | | | 2.651 |
| 1080 | | | 2.907 | 2.741 | 2.573 | 2.403 | | | | 2.640 |
| 1095 | | | 2.895 | 2.729 | 2.561 | 2.392 | 2.220 | | | 2.629 |
| 1110 | | | 2.883 | 2.718 | 2.550 | 2.381 | 2.210 | | | 2.617 |
| 1125 | | 3.034 | 2.871 | 2.706 | 2.539 | 2.370 | 2.200 | 2.027 | | 2.606 |
| 1140 | | 3.022 | 2.859 | 2.694 | 2.528 | 2.360 | 2.189 | 2.017 | 1.843 | 2.595 |
| 1155 | | 3.009 | 2.847 | 2.683 | 2.517 | 2.349 | 2.179 | 2.007 | 1.834 | 2.584 |
| 1170 | | 2.997 | 2.835 | 2.671 | 2.506 | 2.338 | 2.169 | 1.998 | 1.824 | 2.572 |
| 1185 | | 2.985 | 2.823 | 2.660 | 2.495 | 2.327 | 2.158 | 1.988 | 1.815 | 2.561 |
| 1200 | | 2.973 | 2.811 | 2.648 | 2.483 | 2.317 | 2.148 | 1.978 | 1.806 | 2.550 |
| 1215 | 3.120 | 2.961 | 2.800 | 2.637 | 2.472 | 2.306 | 2.138 | 1.968 | 1.796 | 2.538 |
| 1230 | 3.107 | 2.948 | 2.788 | 2.625 | 2.461 | 2.295 | 2.128 | 1.958 | 1.787 | 2.527 |
| 1245 | 3.095 | 2.936 | 2.776 | 2.614 | 2.450 | 2.285 | 2.117 | 1.948 | 1.778 | 2.516 |
| 1260 | 3.082 | 2.924 | 2.764 | 2.602 | 2.439 | 2.274 | 2.107 | 1.938 | 1.768 | 2.504 |
| 1275 | 3.070 | 2.912 | 2.752 | 2.591 | 2.428 | 2.263 | 2.097 | 1.929 | 1.759 | 2.493 |
| 1290 | 3.057 | 2.899 | 2.740 | 2.579 | 2.417 | 2.252 | 2.086 | 1.919 | 1.750 | 2.482 |
| 1305 | 2.045 | 2.887 | 2.728 | 2.568 | 2.405 | 2.242 | 2.076 | 1.909 | 1.740 | 2.470 |
| 1320 | 3.032 | 2.875 | 2.716 | 2.556 | 2.394 | 2.231 | 2.066 | 1.899 | 1.731 | 2.459 |
| 1335 | 3.019 | 2.863 | 2.704 | 2.545 | 2.383 | 2.220 | 2.055 | 1.889 | 1.722 | 2.448 |
| 1350 | 3.007 | 2.851 | 2.693 | 2.533 | 2.372 | 2.209 | 2.045 | 1.879 | 1.712 | 2.437 |

TABLE 97 b. Two-dimensional equations and statistical parameters

$\rho = a + bT + cC + dC^2 + eTC^2$ ($gcm^{-3}$)

| $a$ | $b \cdot 10^4$ | $c \cdot 10^2$ | $d \cdot 10^5$ | $e \cdot 10^8$ | Max. percent departure | Stand. error of est. |
|---|---|---|---|---|---|---|
| 6.05239 | −9.55399 | −2.73976 | −7.58455 | 3.31696 | 0.30 (1343.2K, 70 mol % KF) | 0.004 |

Reference: [98]. Data reported in equation form.

$C$ = mol percent KF.

TABLE 98 a. KF-$LaF_3$: Density

Numerical values ($gcm^{-3}$)

Mol percent $LaF_3$

| $T$ | 40.0 | 30.0 | 20.0 | 10.0 | 0.0 |
|---|---|---|---|---|---|
| 1050 | | | 2.593 | | |
| 1065 | | | 2.581 | | |
| 1080 | | 2.908 | 2.570 | | |
| 1095 | | 2.897 | 2.559 | 2.222 | |
| 1110 | | 2.885 | 2.547 | 2.212 | |
| 1125 | | 2.874 | 2.536 | 2.201 | |
| 1140 | | 2.862 | 2.525 | 2.191 | 1.844 |
| 1155 | | 2.851 | 2.513 | 2.181 | 1.834 |
| 1170 | | 2.839 | 2.502 | 2.170 | 1.825 |
| 1185 | | 2.828 | 2.491 | 2.160 | 1.815 |
| 1200 | | 2.816 | 2.479 | 2.149 | 1.806 |
| 1215 | 3.114 | 2.805 | 2.468 | 2.139 | 1.797 |
| 1230 | 3.102 | 2.793 | 2.457 | 2.129 | 1.787 |
| 1245 | 3.090 | 2.782 | 2.445 | 2.118 | 1.778 |
| 1260 | 3.078 | 2.770 | 2.434 | 2.108 | 1.769 |
| 1275 | 3.066 | 2.759 | 2.423 | 2.097 | 1.759 |
| 1290 | 3.054 | 2.747 | 2.411 | 2.087 | 1.750 |
| 1305 | 3.042 | 2.735 | 2.400 | 2.076 | 1.741 |
| 1320 | 3.030 | 2.724 | 2.389 | 2.066 | 1.731 |
| 1335 | 3.018 | 2.712 | 2.377 | 2.056 | 1.722 |
| 1350 | 3.006 | 2.701 | 2.366 | 2.045 | 1.712 |

TABLE 98 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % $LaF_3$) | $a$ | $b \cdot 10^4$ | Stand. dev. [98] |
|---|---|---|---|
| 0.0 | 2.555 | −6.241 | 0.00276 |
| 10.0 | 2.983 | −6.947 | 0.00447 |
| 20.0 | 3.386 | −7.555 | 0.00510 |
| 30.0 | 3.738 | −7.682 | 0.00595 |
| 40.0 | 4.090 | −8.030 | 0.00492 |

Reference: [98]. Data reported in equation form.

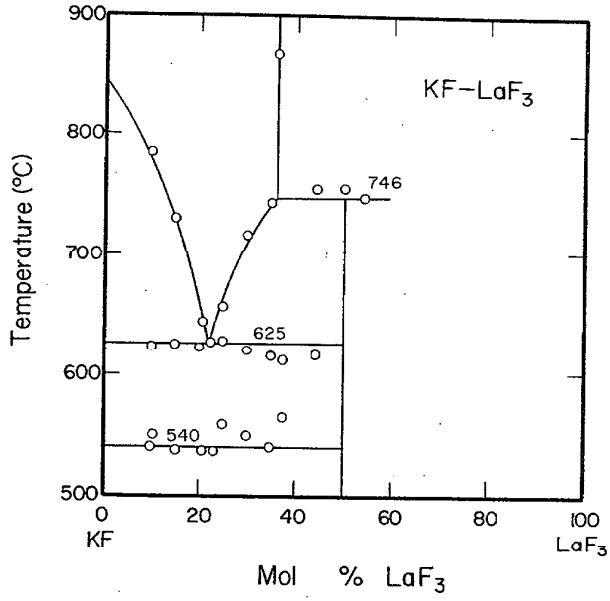


FIGURE 26. Temperature-composition phase diagram for KF-$LaF_3$. G. A. Bukhalova, E. P. Babaeva, and T. M. Khliyan, Russ. J. Inorg. Chem., **10**, 1158 (1965).

## KF-LiF

### Electrical Conductance

The recommended values in table 102 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [87].

TABLE 99 A. Investigations critically re-examined

| Ref. | LiF (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0–100 | 1013–1343 |

TABLE 99 B. Comparisons with previous recommendations

| Ref. | Recommended value | | LiF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | %(min) | ($T$) | % (max) | ($T$) |
| 87 | 1 | 2 | 100 | 5.0 | (1160) | 6.8 | (1270) |
| 87 | 1 | 3 | 0 | 3.5 | (1280) | 4.5 | (1140) |

TABLE 99 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket[87]. | Mo[87] | 20–20,000 measurements at 10,000 [87] |

Comment: Brief remarks concerning reference [87] are discussed under the system $CaF_2$–LiF.

## Density

The recommended values in table 103 are based on the work of Porter and Meaker (Archimedean method) [98].

TABLE 100 A. Investigations critically re-examined

| Ref. | LiF (mol %) | Temp. range ($T$) |
|---|---|---|
| 47 | 50 | 788–1011 |
| 89 | 0–100 (graphical) | 1073, 1173, 1273 |
| 48 | 50 | 788–1011 |
| 87 | 0–100 (graphical) | 1273 |
| **98** | 0–100 | 973–1353 |
| 30 | 50 | 873, 973, 1073 |

TABLE 100 B. Comparisons with previous recommendations

| Ref. | Recommended value | | LiF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | %(min) | ($T$) | % (max) | ($T$) |
| **98** | 1 | 2 | 100 | −4.5 | (1310) | −5.6 | (1150) |
| **98** | 1 | 3 | 0 | −3.1 | (1140–1280) | | |

TABLE 100 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Tungsten, molybdenum or nickle bob suspended by a W or Mo wire, melt contained in a Mo crucible [89] | |
| Pt sphere and Pt suspension wire [48] | Water [48] |
| Biconical Mo plummet suspended from Mo wire, melt contained in graphite crucible [87, **98**] | Molten KCl [87, **98**] |

Comment: Brief remarks concerning reference [98] are given under the system NaF–$ThF_4$. Density values in reference [98] were reported in the form of linear temperature-dependent equations with standard deviations in the range: $2.76 \times 10^{-3}$ gcm$^{-3}$ (0 mol % LiF) to $10.6 \times 10^{-3}$ gcm$^{-3}$ (70 mol % LiF).

## Surface Tension

The recommended values in figure 27 are based on the work of Mellors and Senderoff (maximum bubble pressure method) [89].

TABLE 101 A. Investigations critically re-examined

| Ref. | LiF (mol %) | Temp. range ($T$) |
|---|---|---|
| **89** | 0, 25, 50, 75, 100 (graphical) | 1023–1273 |

Comment: Mellors and Senderoff [89] corrected for the expansion of the bubble tip with temperature. The accuracy of their method was reported to be ±0.5 dyn cm$^{-1}$.

## Melt Preparation and Purification

Mellors and Senderoff [89] used ACS specified reagents (Harshaw Chemical Company).

The procedure used by Porter et al. [87, 98] is discussed under the system $CaF_2$-LiF.

TABLE 102. KF-LiF: Electrical conductance

Specific conductance: Numerical values (ohm$^{-1}$ cm$^{-1}$)

| | Mol percent LiF | | | | | | |
|---|---|---|---|---|---|---|---|
| $T$ | 100.0 | 85.0 | 70.0 | 50.0 | 35.0 | 20.0 | 0.0 |
| 1020 | | | | 3.00 | 2.96 | | |
| 1030 | | | | 3.04 | 3.00 | | |
| 1040 | | | | 3.08 | 3.04 | | |
| 1050 | | | | 3.13 | 3.08 | | |
| 1060 | | | | 3.17 | 3.12 | | |
| 1070 | | | | 3.22 | 3.16 | | |
| 1080 | | | | 3.26 | 3.20 | | |
| 1090 | | | | 3.31 | 3.24 | | |
| 1100 | | | 4.13 | 3.35 | 3.28 | | |
| 1110 | | | 4.18 | 3.40 | 3.32 | 3.41 | |
| 1120 | | | 4.22 | 3.44 | 3.37 | 3.45 | |
| 1130 | | 5.82 | 4.27 | 3.48 | 3.41 | 3.48 | |
| 1140 | | 5.88 | 4.31 | 3.53 | 3.45 | 3.52 | 3.74 |
| 1150 | 9.10 | 5.93 | 4.36 | 3.57 | 3.49 | 3.55 | 3.77 |
| 1160 | 9.16 | 5.99 | 4.41 | 3.62 | 3.53 | 3.58 | 3.80 |
| 1170 | 9.22 | 6.04 | 4.45 | 3.66 | 3.57 | 3.62 | 3.83 |
| 1180 | 9.27 | 6.10 | 4.50 | 3.71 | 3.61 | 3.65 | 3.86 |
| 1190 | 9.33 | 6.15 | 4.54 | 3.75 | 3.65 | 3.69 | 3.89 |
| 1200 | 9.39 | 6.21 | 4.59 | 3.80 | 3.69 | 3.72 | 3.92 |
| 1210 | 9.45 | 6.26 | 4.64 | 3.84 | 3.73 | 3.76 | 3.95 |
| 1220 | 9.51 | 6.32 | 4.68 | 3.89 | 3.77 | 3.79 | 3.98 |
| 1230 | 9.57 | 6.37 | 4.73 | 3.93 | 3.81 | 3.82 | 4.01 |
| 1240 | 9.62 | 6.43 | 4.78 | 3.97 | 3.85 | 3.86 | 4.03 |
| 1250 | 9.68 | 6.48 | 4.82 | 4.02 | 3.89 | 3.89 | 4.06 |
| 1260 | 9.74 | 6.54 | 4.87 | 4.06 | 3.93 | 3.93 | 4.09 |
| 1270 | 9.80 | 6.59 | 4.91 | 4.11 | 3.97 | 3.96 | 4.12 |
| 1280 | 9.86 | 6.65 | 4.96 | 4.15 | 4.02 | 4.00 | 4.15 |
| 1290 | 9.92 | 6.70 | 5.01 | 4.20 | 4.06 | 4.03 | 4.18 |
| 1300 | 9.97 | 6.76 | 5.05 | 4.24 | 4.10 | 4.07 | 4.21 |
| 1310 | 10.03 | 6.81 | 5.10 | 4.29 | 4.14 | 4.10 | 4.24 |
| 1320 | 10.09 | 6.87 | 5.14 | 4.33 | 4.18 | 4.13 | 4.27 |
| 1330 | 10.15 | 6.92 | 5.19 | 4.37 | 4.22 | 4.17 | 4.30 |
| 1340 | 10.21 | 6.97 | 5.24 | 4.42 | 4.26 | 4.20 | 4.33 |

TABLE 102 b. Temperature-dependent equations

$\kappa = a + bT$ (ohm$^{-1}$ cm$^{-1}$)

| Comp. (mol % LiF) | $a \cdot 10^1$ | $b \cdot 10^3$ | Stand. dev. [87] |
|---|---|---|---|
| 0.0 | 3.884 | 2.940 | 0.0179 |
| 20.0 | −3.994 | 3.434 | 0.0253 |
| 35.0 | −11.87 | 4.064 | 0.0390 |
| 50.0 | −15.42 | 4.448 | 0.0348 |
| 70.0 | −9.417 | 4.610 | 0.0280 |
| 85.0 | −3.625 | 5.475 | 0.0310 |
| 100.0 | 23.95 | 5.830 | 0.0500 |

Reference: [87]. Data reported in equation form.

TABLE 103 a. KF-LiF: Density

Numerical values (gcm$^{-3}$)

Mol percent LiF

| $T$ | 100.0 | 85.0 | 70.0 | 50.0 | 35.0 | 20.0 | 0.0 |
|---|---|---|---|---|---|---|---|
| 980 | | | | | 1.909 | | |
| 1000 | | | | | 1.897 | | |
| 1020 | | | | | 1.885 | | |
| 1040 | | | | | 1.873 | | |
| 1060 | | | | | 1.862 | | |
| 1080 | | | | | 1.850 | 1.870 | |
| 1100 | | | | | 1.838 | 1.858 | |
| 1120 | | 1.756 | 1.721 | 1.806 | 1.826 | 1.847 | |
| 1140 | 1.695 | 1.746 | 1.711 | 1.796 | 1.815 | 1.835 | 1.844 |
| 1160 | 1.689 | 1.737 | 1.701 | 1.785 | 1.803 | 1.824 | 1.831 |
| 1180 | 1.682 | 1.728 | 1.692 | 1.774 | 1.791 | 1.813 | 1.819 |
| 1200 | 1.675 | 1.718 | 1.682 | 1.764 | 1.779 | 1.801 | 1.806 |
| 1220 | 1.669 | 1.709 | 1.672 | 1.753 | 1.768 | 1.790 | 1.794 |
| 1240 | 1.662 | 1.700 | 1.662 | 1.742 | 1.756 | 1.779 | 1.781 |
| 1260 | 1.656 | 1.690 | 1.652 | 1.731 | 1.744 | 1.767 | 1.769 |
| 1280 | 1.649 | 1.681 | 1.642 | 1.721 | 1.732 | 1.756 | 1.756 |
| 1300 | 1.642 | 1.672 | 1.632 | 1.710 | 1.721 | 1.745 | 1.744 |
| 1320 | 1.636 | 1.662 | 1.623 | 1.699 | 1.709 | 1.733 | 1.731 |
| 1340 | 1.629 | 1.653 | 1.613 | 1.688 | 1.697 | 1.722 | 1.719 |

TABLE 103 b. Temperature-dependent equations

$\rho = a + bT$ (gcm$^{-3}$)

| Comp. (mol % LiF) | $a$ | $b \cdot 10^4$ | Stand. dev. [98] |
|---|---|---|---|
| 0.0 | 2.555 | −6.241 | 0.00276 |
| 20.0 | 2.483 | −5.680 | 0.00690 |
| 35.0 | 2.484 | −5.872 | 0.00596 |
| 50.0 | 2.407 | −5.362 | 0.00357 |
| 70.0 | 2.273 | −4.927 | 0.0106 |
| 85.0 | 2.278 | −4.663 | 0.00610 |
| 100.0 | 2.074 | −3.321 | 0.00705 |

Reference: [98]. Data reported in equation form.

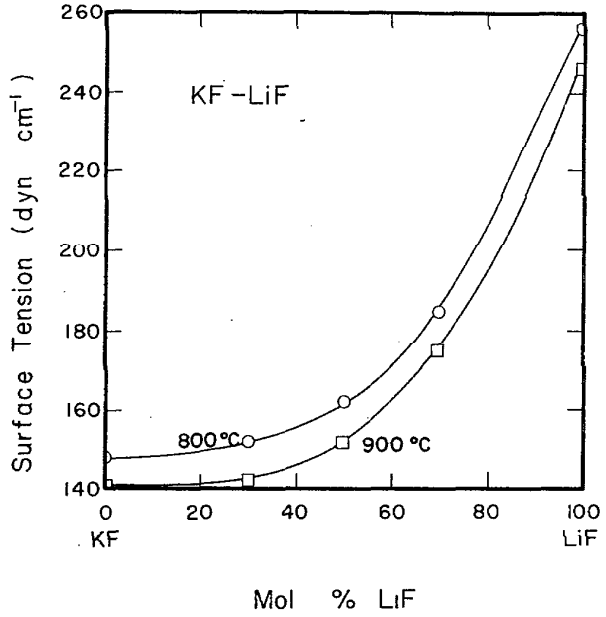


FIGURE 27. Isotherms [89] (°C) of surface tension against molar composition for the system KF-LiF.

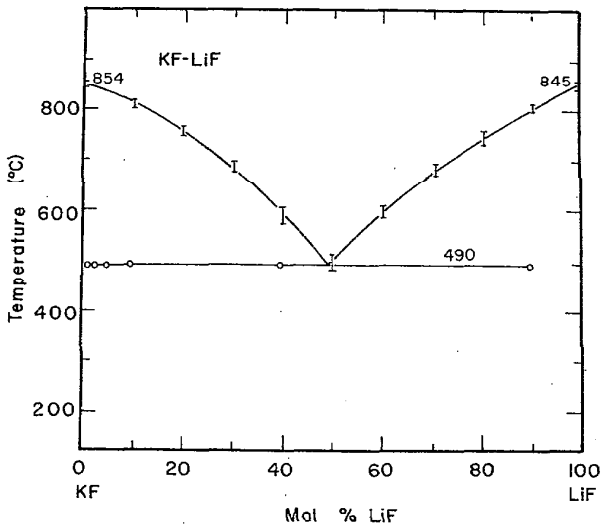


FIGURE 28. Temperature-composition phase diagram for KF-LiF.
A. G. Bergman and N. A. Bychkova-Shul'ga,
Zh. Neorg. Khim. **2**, 179 (1957).
[J. Inorg. Chem. USSR, **2**, No. 1, 276 (1957)].
E. Akrust, B. Bjorge, H. Flood, and T. Forland,
Ann. N.Y. Acad. Sci., **79**, 830 (1960).

## KF-NaF

### Electrical Conductance

The recommended values in table 107 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [87].

TABLE 104 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range ($T$) |
|---|---|---|
| 14 | 0–100 | 1023–1323 |
| 87 | 0–100 | 1043–1343 |

TABLE 104 B. Comparisons with previous recommendations

| Ref | Recommended value | | NaF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 14 | 1 | 3 | 100 | −8.8 | (1323) | −18.8 | (1273) |
| 87 | 1 | 3 | 100 | 5.5 | (1310) | 8.3 | (1360) |
| 14 | 4.1 | 60 | 100 | −14.1 | (1323) | −15.7 | (1313) |
| 14 | 4.1 | 60 | 80 | −14.3 | (1273) | −18.1 | (1223) |
| 14 | 4.1 | 60 | 60 | −15.0 | (1273) | −23.9 | (1223) |
| 14 | 4.1 | 60 | 40 | −6.5 | (1323) | −22.8 | (1073) |
| 14 | 4.1 | 60 | 0 | −18.9 | (1273) | −31.2 | (1153) |
| 14 | 1 | 3 | 0 | −16.0 | (1273) | −28.2 | (1153) |
| 87 | 1 | 3 | 0 | 3.5 | (1280) | 4.5 | (1140) |

TABLE 104 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) | Calibration |
|---|---|---|---|
| Pt crucible [14] | Pt crucible and Pt disc [14] | 20–20,000 measurements at 10,000 [87] | KCl solution at 18° C [14] |
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | | |

Comment: Batashev [14] reported an accuracy of 2–3 percent for conductivity measurements. Remarks concerning reference [87] are discussed under the system $CaF_2$-LiF.

### Density

The recommended values in table 108 are based on the work of Porter and Meaker (Archimedean method) [98].

TABLE 105 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range ($T$) |
|---|---|---|
| 89 | 40 (eutectic, graphical) | 1023–1153 |
| 87 | 0–100 (graphical) | 1273 |
| 98 | 0–100 | 1043–1353 |

TABLE 105 B. Comparisons with previous recommendations

| Ref. | Recommended value | | NaF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 98 | 1 | 3 | 100 | −2.2 | (1280) | −2.5 | (1340) |
| 98 | 1 | 3 | 0 | −3.1 | (1140–1280) | | |

TABLE 105 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| W, Mo, or Ni bob suspended by W or Mo wire, melt contained in Mo crucible [89] | Molten KCl [87, 98] |
| Mo plummet connected to quartz spring by Mo wire, melt contained in graphite crucible [87, 98] | |

Comment: Remarks concerning reference [98] are under the system $CaF_2$-LiF. Density values were reported in the form of linear temperature equations with standard deviations in the range: $2.30 \times 10^{-3}$ gcm$^{-3}$ (80 mol % NaF) to $18.7 \times 10^{-3}$ (12 mol % NaF).

### Surface Tension

The recommended values in figure 29 are based on the work of Mellors and Senderoff (maximum bubble pressure method) [89].

TABLE 106 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range ($T$) |
|---|---|---|
| 89 | 40 (eutectic, graphical) | 973–1198 |

Comment: Remarks concerning reference [89] are under the system KF-LiF.

### Melt Preparation and Purification

Batashev [14] dehydrated sodium and potassium fluoride (obtained from Kahlbaum) by melting the salts in a platinum cup. Analysis of KF gave the results: K, 67.27 percent (theoretical 67.30%) and F, 32.51 percent (32.70); and results of NaF showed: Na, 54.63 percent (54.76) and F, 44.99 percent (45.24).

Salts in reference [89] were ACS grade (obtained from Harshaw Chemical Company).

The melt preparation procedure used by Porter et al. [87, 98] is discussed under the system $CaF_2$-LiF.

TABLE 107a. KF-NaF: Electrical conductance

Specific conductance: Numerical values ($ohm^{-1}$ $cm^{-1}$)

Mol Percent NaF

| $T$ | 100.0 | 80.0 | 60.0 | 40.0 | 25.0 | 12.0 | 0.0 |
|---|---|---|---|---|---|---|---|
| 1050 | | | | 3.21 | | | |
| 1060 | | | | 3.25 | | | |
| 1070 | | | | 3.28 | | | |
| 1080 | | | | 3.32 | 3.41 | | |
| 1090 | | | | 3.36 | 3.45 | 3.45 | |
| 1100 | | | | 3.39 | 3.49 | 3.48 | |
| 1110 | | | 3.76 | 3.43 | 3.53 | 3.52 | |
| 1120 | | | 3.79 | 3.46 | 3.57 | 3.55 | |
| 1130 | | | 3.83 | 3.50 | 3.61 | 3.59 | |
| 1140 | | | 3.86 | 3.54 | 3.65 | 3.62 | 3.74 |
| 1150 | | | 3.90 | 3.57 | 3.69 | 3.66 | 3.77 |
| 1160 | | | 3.93 | 3.61 | 3.73 | 3.69 | 3.80 |
| 1170 | | | 3.97 | 3.64 | 3.76 | 3.73 | 3.83 |
| 1180 | | | 4.00 | 3.68 | 3.80 | 3.76 | 3.86 |
| 1190 | | | 4.04 | 3.71 | 3.84 | 3.80 | 3.89 |
| 1200 | | | 4.07 | 3.75 | 3.88 | 3.83 | 3.92 |
| 1210 | | | 4.11 | 3.79 | 3.92 | 3.87 | 3.95 |
| 1220 | | | 4.14 | 3.82 | 3.96 | 3.91 | 3.98 |
| 1230 | | 4.39 | 4.18 | 3.86 | 4.00 | 3.94 | 4.01 |
| 1240 | | 4.42 | 4.21 | 3.89 | 4.04 | 3.98 | 4.03 |
| 1250 | | 4.46 | 4.25 | 3.93 | 4.08 | 4.01 | 4.06 |
| 1260 | | 4.49 | 4.28 | 3.96 | 4.12 | 4.05 | 4.09 |
| 1270 | | 4.52 | 4.32 | 4.00 | 4.16 | 4.08 | 4.12 |
| 1280 | | 4.56 | 4.35 | 4.04 | 4.20 | 4.12 | 4.15 |
| 1290 | | 4.59 | 4.39 | 4.07 | 4.24 | 4.15 | 4.18 |
| 1300 | | 4.63 | 4.42 | 4.11 | 4.28 | 4.19 | 4.21 |
| 1310 | 5.33 | 4.66 | 4.46 | 4.14 | 4.32 | 4.22 | 4.24 |
| 1320 | 5.39 | 4.69 | 4.49 | 4.18 | 4.36 | 4.26 | 4.27 |
| 1330 | 5.44 | 4.73 | 4.53 | 4.22 | 4.40 | 4.29 | 4.30 |
| 1340 | 5.50 | 4.76 | 4.56 | 4.25 | 4.44 | 4.33 | 4.33 |

TABLE 107 b. Temperature-dependent equations

$\kappa = a + bT$ ($ohm^{-1}$ $cm^{-1}$)

| Comp. (mol % NaF) | $a \cdot 10^1$ | $b \cdot 10^3$ | Stand. dev. [87] |
|---|---|---|---|
| 0.0 | 3.884 | 2.940 | 0.0179 |
| 12.0 | −3.959 | 3.525 | 0.0253 |
| 25.0 | −8.667 | 3.958 | 0.0100 |
| 40.0 | −5.467 | 3.580 | 0.0420 |
| 60.0 | −1.282 | 3.500 | 0.0226 |
| 80.0 | 1.797 | 3.420 | 0.0280 |
| 100.0 | −20.60 | 5.640 | 0.0660 |

Reference: [87]. Data reported in equation form.

TABLE 108 a. KF-NaF: Density

Numerical values ($gcm^{-3}$)

Mol percent NaF

| $T$ | 100.0 | 80.0 | 60.0 | 40.0 | 25.0 | 12.0 | 0.0 |
|---|---|---|---|---|---|---|---|
| 1050 | | | | 1.938 | | | |
| 1065 | | | | 1.929 | 1.810 | | |
| 1080 | | | | 1.920 | 1.806 | | |
| 1095 | | | | 1.911 | 1.802 | 1.756 | |
| 1110 | | | | 1.902 | 1.797 | 1.755 | |
| 1125 | | | 1.895 | 1.893 | 1.793 | 1.753 | |
| 1140 | | | 1.887 | 1.884 | 1.789 | 1.752 | 1.844 |
| 1155 | | | 1.878 | 1.875 | 1.784 | 1.750 | 1.834 |
| 1170 | | | 1.870 | 1.866 | 1.780 | 1.749 | 1.825 |
| 1185 | | | 1.862 | 1.857 | 1.776 | 1.747 | 1.815 |
| 1200 | | 1.896 | 1.853 | 1.848 | 1.772 | 1.746 | 1.806 |
| 1215 | | 1.887 | 1.845 | 1.839 | 1.767 | 1.744 | 1.797 |
| 1230 | | 1.878 | 1.836 | 1.830 | 1.763 | 1.743 | 1.787 |
| 1245 | | 1.869 | 1.828 | 1.821 | 1.759 | 1.741 | 1.778 |
| 1260 | | 1.860 | 1.819 | 1.812 | 1.755 | 1.740 | 1.769 |
| 1275 | 1.898 | 1.852 | 1.811 | 1.803 | 1.750 | 1.738 | 1.759 |
| 1290 | 1.889 | 1.843 | 1.802 | 1.794 | 1.746 | 1.737 | 1.750 |
| 1305 | 1.879 | 1.834 | 1.794 | 1.785 | 1.742 | 1.735 | 1.741 |
| 1320 | 1.870 | 1.825 | 1.785 | 1.776 | 1.737 | 1.734 | 1.731 |
| 1335 | 1.861 | 1.816 | 1.777 | 1.767 | 1.733 | 1.732 | 1.722 |
| 1350 | 1.852 | 1.807 | 1.768 | 1.758 | 1.729 | 1.731 | 1.712 |

TABLE 108 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % NaF) | $a$ | $b \cdot 10^4$ | Stand. deviation [98] |
|---|---|---|---|
| 0.0 | 2.555 | −6.241 | 0.00276 |
| 12.0 | 1.867 | −1.011 | 0.0187 |
| 25.0 | 2.114 | −2.853 | 0.0145 |
| 40.0 | 2.568 | 6.000 | 0.0130 |
| 60.0 | 2.530 | −5.641 | 0.00279 |
| 80.0 | 2.601 | −5.878 | 0.00230 |
| 100.0 | 2.682 | −6.151 | 0.00239 |

Reference: [98]. Data reported in equation form. Two-dimensional statistical analysis was unsuccessful.

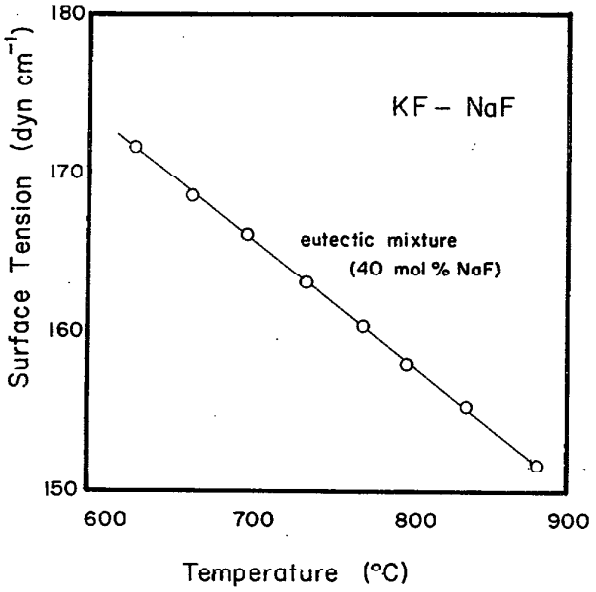


FIGURE 29. Plot [89] of surface tension against temperature for the system KF-NaF.

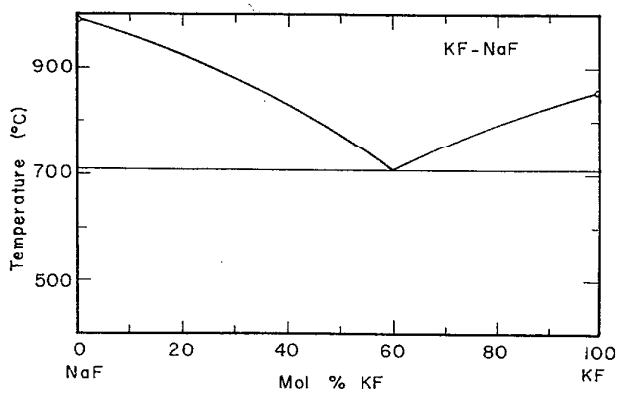


FIGURE 30. Temperature-composition phase diagram for KF-NaF. A. G. Bergman and E. P. Dergunov, "Fusion Diagram of LiF-KF-NaF," Compt. Rend. Acad. Sci. USSR. **31**, 753–54 (1941).

## $KF\text{-}SmF_3$

### Electrical Conductance

The recommended values in table 111 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [87].

TABLE 109 A. Investigations critically re-examined

| Ref. | $SmF_3$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0, 10.0, 20.0, 30.0, 40.0, 50.0 | 1063–1343 |

TABLE 109 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $SmF_3$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 87 | 1 | 3 | 0 | 3.5 | (1280) | 4.5 | (1140) |

TABLE 109 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

### Density

The recommended values in table 112 are based on the work of Meaker, Porter, and Kesterke (Archimedean method) [87].

TABLE 110 A. Investigations critically re-examined

| Ref. | $SmF_3$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 10.0, 20.0, 30.0, 40.0, 50.0 | 1100–1343 |

TABLE 110 B. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [87] | Molten KCl [87] |

### Melt Preparation and Purification

Reagent-grade chemicals were used in references [87] and [98]. After vacuum drying at 400 °C the salts were cooled and combined in the correct proportions. The salts were then placed in graphite crucibles and heated under vacuum (50 $\mu$m Hg) to 600 °C. For density and conductance measurements the mixtures were melted in an atmosphere of helium in a controlled-atmosphere chamber. Melt compositions were confirmed by analysis after density measurements.

TABLE 111 b. Temperature-dependent equations

$\kappa = a + bT$ (ohm$^{-1}$ cm$^{-1}$)

| Comp. (mol % SmF) | $a$ | $b \cdot 10^3$ | Stand. deviation [87] |
|---|---|---|---|
| 0.0 | 0.388 | 2.940 | 0.0179 |
| 10.0 | −1.798 | 3.953 | 0.0155 |
| 20.0 | −1.697 | 3.226 | 0.0067 |
| 30.0 | −1.523 | 2.736 | 0.0138 |
| 40.0 | −2.293 | 3.196 | 0.0078 |
| 50.0 | −2.771 | 3.550 | 0.0053 |

Reference: [87]. Data reported in equation form.

TABLE 111 a. $KF$-$SmF_3$: Electrical conductance

Specific conductance: Numerical values (ohm $^{-1}$ cm $^{-1}$)

Mol percent $SmF_3$

| $T$ | 50.0 | 40.0 | 30.0 | 20.0 | 10.0 | 0.0 |
|---|---|---|---|---|---|---|
| 1070 | | | | | 2.43 | |
| 1080 | | | | | 2.47 | |
| 1090 | | | | | 2.51 | |
| 1100 | | | | 1.85 | 2.55 | |
| 1110 | | | | 1.88 | 2.59 | |
| 1120 | | | | 1.92 | 2.63 | |
| 1130 | | 1.32 | | 1.95 | 2.67 | |
| 1140 | | 1.35 | | 1.98 | 2.71 | 3.74 |
| 1150 | | 1.38 | | 2.01 | 2.75 | 3.77 |
| 1160 | | 1.41 | | 2.05 | 2.79 | 3.80 |
| 1170 | | 1.45 | | 2.08 | 2.83 | 3.83 |
| 1180 | | 1.48 | | 2.11 | 2.87 | 3.86 |
| 1190 | | 1.51 | 1.73 | 2.14 | 2.91 | 3.89 |
| 1200 | | 1.54 | 1.76 | 2.17 | 2.95 | 3.92 |
| 1210 | | 1.57 | 1.79 | 2.21 | 2.99 | 3.95 |
| 1220 | | 1.61 | 1.81 | 2.24 | 3.02 | 3.98 |
| 1230 | | 1.64 | 1.84 | 2.27 | 3.06 | 4.01 |
| 1240 | | 1.67 | 1.87 | 2.30 | 3.10 | 4.03 |
| 1250 | 1.67 | 1.70 | 1.90 | 2.34 | 3.14 | 4.06 |
| 1260 | 1.70 | 1.73 | 1.92 | 2.37 | 3.18 | 4.09 |
| 1270 | 1.74 | 1.77 | 1.95 | 2.40 | 3.22 | 4.12 |
| 1280 | 1.77 | 1.80 | 1.98 | 2.43 | 3.26 | 4.15 |
| 1290 | 1.81 | 1.83 | 2.01 | 2.46 | 3.30 | 4.18 |
| 1300 | 1.84 | 1.86 | 2.03 | 2.50 | 3.34 | 4.21 |
| 1310 | 1.88 | 1.89 | 2.06 | 2.53 | 3.38 | 4.24 |
| 1320 | 1.92 | 1.93 | 2.09 | 2.56 | 3.42 | 4.27 |
| 1330 | 1.95 | 1.96 | 2.12 | 2.59 | 3.46 | 4.30 |
| 1340 | 1.99 | 1.99 | 2.14 | 2.63 | 3.50 | 4.33 |

TABLE 112 a. $KF$–$SmF_3$: Density

Numerical values (gcm$^{-3}$)

Mol percent $SmF_3$

| $T$ | 50.0 | 40.0 | 30.0 | 20.0 | 10.0 | 0.0 |
|---|---|---|---|---|---|---|
| 1100 | | | | 2.678 | 2.286 | |
| 1110 | | | | 2.670 | 2.280 | |
| 1120 | | | | 2.663 | 2.273 | |
| 1130 | | 3.445 | 3.051 | 2.655 | 2.266 | |
| 1140 | | 3.437 | 3.043 | 2.647 | 2.259 | 1.844 |
| 1150 | | 3.428 | 3.034 | 2.640 | 2.252 | 1.837 |
| 1160 | | 3.419 | 3.025 | 2.632 | 2.245 | 1.831 |
| 1170 | | 3.411 | 3.017 | 2.624 | 2.238 | 1.825 |
| 1180 | | 3.402 | 3.008 | 2.617 | 2.232 | 1.819 |
| 1190 | | 3.394 | 3.000 | 2.609 | 2.225 | 1.812 |
| 1200 | | 3.385 | 2.991 | 2.602 | 2.218 | 1.806 |
| 1210 | | 3.377 | 2.982 | 2.594 | 2.211 | 1.800 |
| 1220 | | 3.368 | 2.974 | 2.586 | 2.204 | 1.794 |
| 1230 | 3.838 | 3.359 | 2.965 | 2.579 | 2.197 | 1.787 |
| 1240 | 3.831 | 3.351 | 2.956 | 2.571 | 2.191 | 1.781 |
| 1250 | 3.825 | 3.342 | 2.948 | 2.564 | 2.184 | 1.775 |
| 1260 | 3.818 | 3.334 | 2.939 | 2.556 | 2.177 | 1.769 |
| 1270 | 3.812 | 3.325 | 2.931 | 2.548 | 2.170 | 1.762 |
| 1280 | 3.805 | 3.316 | 2.922 | 2.541 | 2.163 | 1.756 |
| 1290 | 3.799 | 3.308 | 2.913 | 2.533 | 2.156 | 1.750 |
| 1300 | 3.792 | 3.299 | 2.905 | 2.526 | 2.150 | 1.744 |
| 1310 | 3.786 | 3.291 | 2.896 | 2.518 | 2.143 | 1.737 |
| 1320 | 3.779 | 3.282 | 2.888 | 2.510 | 2.136 | 1.731 |
| 1330 | 3.773 | 3.274 | 2.879 | 2.503 | 2.129 | 1.725 |
| 1340 | 3.766 | 3.265 | 2.870 | 2.495 | 2.122 | 1.719 |

TABLE 112 b. Temperature-dependent equations

$\rho = a + bT$ (gcm$^{-3}$)

| Comp. (mol % $SmF_3$) | $a$ | $b \cdot 10^4$ | Stand. deviation [87, 98] |
|---|---|---|---|
| 0.0 | 2.555 | −6.241 | 0.00276 |
| 10.0 | 3.038 | −6.836 | 0.0028 |
| 20.0 | 3.515 | −7.612 | 0.0046 |
| 30.0 | 4.024 | −8.605 | 0.0028 |
| 40.0 | 4.414 | −8.576 | 0.0047 |
| 50.0 | 4.636 | −6.493 | 0.0044 |

References: [87] and [98] (for KF). Data reported in equation form.

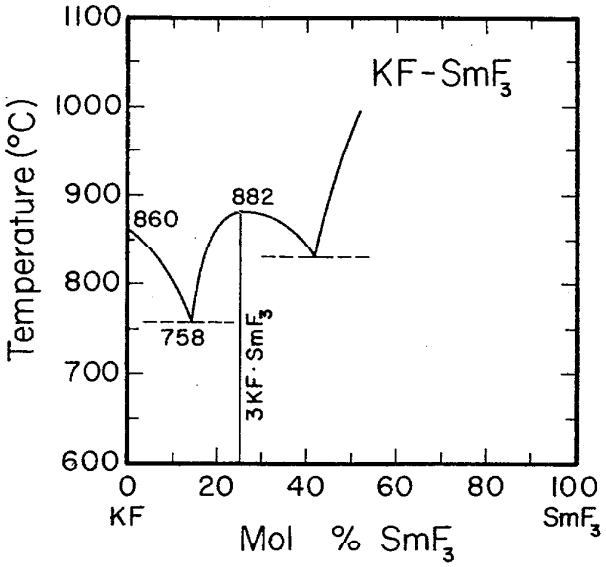


FIGURE 31. Temperature-composition phase diagram for KF-$SmF_3$. E. P. Dergunov, Dokl. Akad. Nauk SSSR, **85** [5] 1027 (1952).

## KF-$ThF_4$

### Electrical Conductance

The recommended values in table 115 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [**87**].

TABLE 113 A. Investigations critically re-examined

| Ref. | $ThF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0.0, 7.1, 13.7, 19.7, 27.5 | 1103–1343 |

TABLE 113 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $ThF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 87 | 1 | 3 | 0 | 3.5 | (1280) | 4.5 | (1140) |

TABLE 113 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

Comment: The specific conductance values measured in reference [87] were reported reproducible to ±1 percent. The precision of the measurements was ±3 percent. The measured resistance was found to be independent of frequency over the range 20 to 20,000 hertz.

### Density

The recommended values in table 116 are based on the work of Meaker and Porter (Archimedean method) [**98**].

TABLE 114 A. Investigations critically re-examined

| Ref. | $ThF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0–28 (graphical) | 1273 |
| 98 | 0.0, 7.1, 13.7, 19.7, 27.5 | 1088–1353 |

TABLE 114 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $ThF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 98 | 1 | 3 | 0 | −3.1 | (1140–1280) | | |

TABLE 114 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [87, 98] | Molten KCl [87, 98] |

Comment: Brief remarks concerning reference [98] are discussed under the system $CaF_2$-LiF.

Density values [98] were reported in the form of linear temperature-dependent equations with standard deviations in the range: $2.76\times10^{-3}$ gcm$^{-3}$ (0 mol % $ThF_4$) to $32.0\times10^{-3}$ gcm$^{-3}$ (7.1 mol % $ThF_4$).

TABLE 115 b. Temperature-dependent equations

$\kappa = a + bT$ (ohm$^{-1}$ cm$^{-1}$)

| Comp. (mol % $ThF_4$) | $a$ | $b\cdot10^3$ | Stand. deviation [87] |
|---|---|---|---|
| 0.0 | 0.388 | 2.940 | 0.0179 |
| 7.1 | −0.962 | 3.284 | 0.0182 |
| 13.7 | −1.099 | 2.952 | 0.0151 |
| 19.7 | −1.474 | 2.783 | 0.00763 |
| 27.5 | −1.718 | 2.668 | 0.00625 |

Reference: [87]. Data reported in equation form.

## Melt Preparation and Purification

The procedure used by Porter et al. [87, 98] for the preparation of pure salts is discussed under the system $CaF_2$-LiF. Thorium tetrafluoride contained less than 0.1 weight-percent of metallic impurities.

TABLE 115 a. KF-$ThF_4$: Electrical conductance

Specific conductance: Numerical values (ohm$^{-1}$ cm$^{-1}$)

Mol percent $ThF_4$

| $T$ | 27.5 | 19.7 | 13.7 | 7.1 | 0.0 |
|---|---|---|---|---|---|
| 1110 | | | | 2.68 | |
| 1120 | | | | 2.72 | |
| 1130 | 1.30 | | | 2.75 | |
| 1140 | 1.32 | | | 2.78 | 3.74 |
| 1150 | 1.35 | | 2.30 | 2.81 | 3.77 |
| 1160 | 1.38 | | 2.33 | 2.85 | 3.80 |
| 1170 | 1.40 | 1.78 | 2.35 | 2.88 | 3.83 |
| 1180 | 1.43 | 1.81 | 2.38 | 2.91 | 3.86 |
| 1190 | 1.46 | 1.84 | 2.41 | 2.95 | 3.89 |
| 1200 | 1.48 | 1.87 | 2.44 | 2.98 | 3.92 |
| 1210 | 1.51 | 1.89 | 2.47 | 3.01 | 3.95 |
| 1220 | 1.54 | 1.92 | 2.50 | 3.04 | 3.98 |
| 1230 | 1.56 | 1.95 | 2.53 | 3.08 | 4.01 |
| 1240 | 1.59 | 1.98 | 2.56 | 3.11 | 4.03 |
| 1250 | 1.62 | 2.00 | 2.59 | 3.14 | 4.06 |
| 1260 | 1.64 | 2.03 | 2.62 | 3.18 | 4.09 |
| 1270 | 1.67 | 2.06 | 2.65 | 3.21 | 4.12 |
| 1280 | 1.70 | 2.09 | 2.68 | 3.24 | 4.15 |
| 1290 | 1.72 | 2.12 | 2.71 | 3.27 | 4.18 |
| 1300 | 1.75 | 2.14 | 2.74 | 3.31 | 4.21 |
| 1310 | 1.78 | 2.17 | 2.77 | 3.34 | 4.24 |
| 1320 | 1.80 | 2.20 | 2.80 | 3.37 | 4.27 |
| 1330 | 1.83 | 2.23 | 2.83 | 3.41 | 4.30 |
| 1340 | 1.86 | 2.26 | 2.86 | 3.44 | 4.33 |

TABLE 116 a. KF-$ThF_4$: Density

Numerical values (gcm$^{-3}$)

Mol percent $ThF_4$

| $T$ | 27.5 | 19.7 | 13.7 | 7.1 | 0.0 |
|---|---|---|---|---|---|
| 1090 | | | 2.714 | | |
| 1100 | | | 2.706 | 2.311 | |
| 1110 | | | 2.697 | 2.301 | |
| 1120 | 3.297 | | 2.689 | 2.291 | |
| 1130 | 3.289 | | 2.680 | 2.281 | |
| 1140 | 3.281 | | 2.672 | 2.271 | 1.844 |
| 1150 | 3.272 | | 2.664 | 2.262 | 1.837 |
| 1160 | 3.264 | 2.945 | 2.655 | 2.252 | 1.831 |
| 1170 | 3.256 | 2.936 | 2.647 | 2.242 | 1.825 |
| 1180 | 3.247 | 2.927 | 2.639 | 2.232 | 1.819 |
| 1190 | 3.239 | 2.918 | 2.630 | 2.223 | 1.812 |
| 1200 | 3.231 | 2.910 | 2.622 | 2.213 | 1.806 |
| 1210 | 3.222 | 2.901 | 2.614 | 2.203 | 1.800 |
| 1220 | 3.214 | 2.892 | 2.605 | 2.193 | 1.794 |
| 1230 | 3.206 | 2.883 | 2.597 | 2.184 | 1.787 |
| 1240 | 3.197 | 2.874 | 2.588 | 2.174 | 1.781 |
| 1250 | 3.189 | 2.866 | 2.580 | 2.164 | 1.775 |
| 1260 | 3.181 | 2.857 | 2.572 | 2.154 | 1.769 |
| 1270 | 3.172 | 2.848 | 2.563 | 2.144 | 1.762 |
| 1280 | 3.164 | 2.839 | 2.555 | 2.135 | 1.756 |
| 1290 | 3.156 | 2.831 | 2.547 | 2.125 | 1.750 |
| 1300 | 3.147 | 2.822 | 2.538 | 2.115 | 1.744 |
| 1310 | 3.139 | 2.813 | 2.530 | 2.105 | 1.737 |
| 1320 | 3.131 | 2.804 | 2.522 | 2.096 | 1.731 |
| 1330 | 3.122 | 2.795 | 2.513 | 2.086 | 1.725 |
| 1340 | 3.114 | 2.787 | 2.505 | 2.076 | 1.719 |
| 1350 | 3.106 | 2.778 | 2.497 | 2.066 | 1.712 |

TABLE 116 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % $ThF_4$) | $a$ | $b \cdot 10^3$ | Stand. dev. [98] |
|---|---|---|---|
| 0.0 | 2.555 | −0.6241 | 0.00276 |
| 7.1 | 3.385 | −0.9768 | 0.032 |
| 13.7 | 3.625 | −0.8359 | 0.00628 |
| 19.7 | 3.963 | −0.8779 | 0.00913 |
| 27.5 | 4.231 | −0.8335 | 0.00860 |

Reference: [98]. Data reported in equation form. Two-dimensional statistical analysis was unsuccessful.

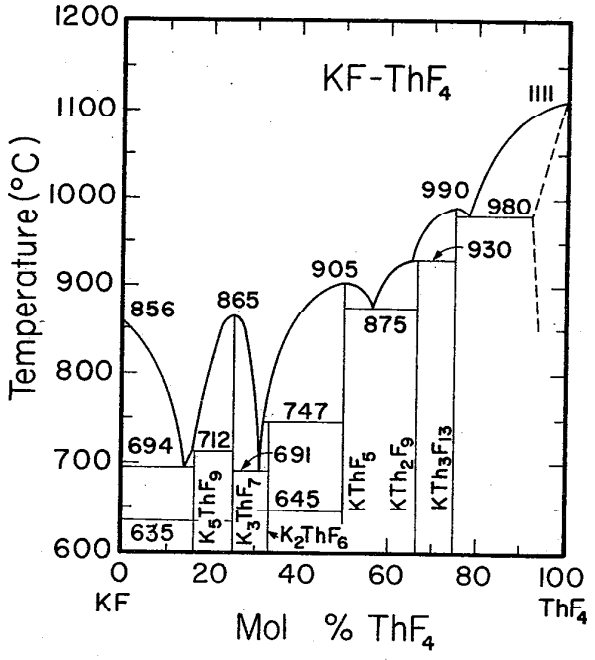


FIGURE 32. Temperature-composition phase diagram for KF-$ThF_4$. W. J. Asker, E. K. Segnit, and A. W. Wylie, J. Chem. Soc. (London), pg. 4471, Nov. 1952.

## KF-$UF_4$

### Electrical Conductance

The recommended values in table 119 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [87].

TABLE 117 A. Investigations critically re-examined

| Ref. | $UF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0, 7. 5, 20, 30, 40, 50 | 1103–1343 |

TABLE 117 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $UF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 87 | 1 | 3 | 0 | 3.5 | (1280) | 4.5 | (1140) |

TABLE 117 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

Comment: The specific conductance values measured in reference [87] were reported reproducible to ±1 percent. The precision of the measurements was ±3 percent. The measured resistance was found to be independent of frequency over the range 20 to 20,000 hertz.

### Density

The recommended values in table 120 are based on the work of Meaker and Porter (Archimedean method) [98].

TABLE 118 A. Investigations critically re-examined

| Ref. | $UF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 40–100 (graphical | 1273 |
| 98 | 0–60 | 1103–1353 |

TABLE 118 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $UF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 98 | 1 | 3 | 0 | −3.1 | (1140–1280) | | |

TABLE 118 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [87, 98] | Molten KCl [87, 98] |

Comment: Remarks concerning reference [98] are given under the system $CaF_2$–LiF.

Density results [98] were reported in the form of linear temperature-dependent equations with standard deviations in the range: $2.76\times10^{-3}$ gcm$^{-3}$ (0 mol % $UF_4$) to $42.9\times10^{-3}$ gcm$^{-3}$ (50 mol % $UF_4$).

TABLE 119 b. Temperature-dependent equations

$\kappa = a + bT$ (ohm$^{-1}$ cm$^{-1}$)

| Comp. (mol % $UF_4$) | $a$ | $b\cdot10^3$ | Stand. dev. [87] |
|---|---|---|---|
| 0.0 | 0.388 | 2.940 | 0.0179 |
| 7.5 | −0.448 | 2.840 | 0.0134 |
| 20.0 | −1.129 | 2.534 | 0.0121 |
| 30.0 | −1.355 | 2.340 | 0.0166 |
| 40.0 | −0.870 | 1.856 | 0.00913 |
| 50.0 | −1.248 | 2.330 | 0.0206 |

Reference: [87]. Data reported in equation form.

### Melt Preparation and Purification

Reagent-grade chemicals were used in references [87] and [98]. After vacuum drying at 400 °C the salts were cooled and combined in the correct proportions. The salts were then placed in graphite crucibles and heated under vacuum (50 microns) to 600 °C. For density and conductance measurements the mixtures were melted in an atmosphere of helium in a controlled-atmosphere chamber. Melt compositions were confirmed by analyses after density measurements.

TABLE 119 a. $KF$–$UF_4$: Electrical conductance

Specific conductance: Numerical values (ohm$^{-1}$ cm$^{-1}$)

Mol percent $UF_4$

| $T$ | 50.0 | 40.0 | 30.0 | 20.0 | 7.5 | 0.0 |
|---|---|---|---|---|---|---|
| 1110 | 1.34 | | | | | |
| 1120 | 1.36 | | | | | |
| 1130 | 1.38 | | | | | |
| 1140 | 1.41 | | | | | 3.74 |
| 1150 | 1.43 | | | | | 3.77 |
| 1160 | 1.45 | | | | | 3.80 |
| 1170 | 1.48 | | | | 2.87 | 3.83 |
| 1180 | 1.50 | 1.32 | | | 2.90 | 3.86 |
| 1190 | 1.52 | 1.34 | | | 2.93 | 3.89 |
| 1200 | 1.55 | 1.36 | | | 2.96 | 3.92 |
| 1210 | 1.57 | 1.38 | 1.48 | | 2.99 | 3.95 |
| 1220 | 1.59 | 1.39 | 1.50 | 1.96 | 3.02 | 3.98 |
| 1230 | 1.62 | 1.41 | 1.52 | 1.99 | 3.04 | 4.01 |
| 1240 | 1.64 | 1.43 | 1.55 | 2.01 | 3.07 | 4.03 |
| 1250 | 1.66 | 1.45 | 1.57 | 2.04 | 3.10 | 4.06 |
| 1260 | 1.69 | 1.47 | 1.59 | 2.06 | 3.13 | 4.09 |
| 1270 | 1.71 | 1.49 | 1.62 | 2.09 | 3.16 | 4.12 |
| 1280 | 1.73 | 1.51 | 1.64 | 2.11 | 3.19 | 4.15 |
| 1290 | 1.76 | 1.52 | 1.66 | 2.14 | 3.22 | 4.18 |
| 1300 | 1.78 | 1.54 | 1.69 | 2.17 | 3.24 | 4.21 |
| 1310 | 1.80 | 1.56 | 1.71 | 2.19 | 3.27 | 4.24 |
| 1320 | 1.83 | 1.58 | 1.73 | 2.22 | 3.30 | 4.27 |
| 1330 | 1.85 | 1.60 | 1.76 | 2.24 | 3.33 | 4.30 |
| 1340 | 1.87 | 1.62 | 1.78 | 2.27 | 3.36 | 4.33 |

TABLE 120 a. $KF$–$UF_4$: Density

Numerical values (gcm$^{-3}$)

Mol percent $UF_4$

| $T$ | 60.0 | 50.0 | 40.0 | 30.0 | 20.0 | 7.5 | 0.0 |
|---|---|---|---|---|---|---|---|
| 1110 | | 4.535 | | | | | |
| 1120 | 5.044 | 4.522 | 3.979 | | | | |
| 1130 | 5.034 | 4.510 | 3.968 | | | 2.299 | |
| 1140 | 5.024 | 4.497 | 3.957 | | | 2.289 | 1.844 |
| 1150 | 5.014 | 4.484 | 3.946 | | | 2.280 | 1.837 |
| 1160 | 5.004 | 4.471 | 3.935 | | | 2.270 | 1.831 |
| 1170 | 4.993 | 4.458 | 3.924 | | | 2.260 | 1.825 |
| 1180 | 4.983 | 4.445 | 3.913 | | | 2.251 | 1.819 |
| 1190 | 4.973 | 4.432 | 3.902 | | | 2.241 | 1.812 |
| 1200 | 4.963 | 4.419 | 3.891 | | | 2.232 | 1.806 |
| 1210 | 4.953 | 4.406 | 3.880 | | | 2.222 | 1.800 |
| 1220 | 4.943 | 4.393 | 3.869 | 3.385 | | 2.212 | 1.794 |
| 1230 | 4.933 | 4.380 | 3.858 | 3.374 | 2.893 | 2.203 | 1.787 |
| 1240 | 4.923 | 4.367 | 3.847 | 3.364 | 2.887 | 2.193 | 1.781 |
| 1250 | 4.913 | 4.354 | 3.835 | 3.354 | 2.880 | 2.183 | 1.775 |
| 1260 | 4.903 | 4.341 | 3.824 | 3.344 | 2.874 | 2.174 | 1.769 |
| 1270 | 4.893 | 4.328 | 3.813 | 3.334 | 2.867 | 2.164 | 1.762 |
| 1280 | 4.882 | 4.315 | 3.802 | 3.324 | 2.861 | 2.154 | 1.756 |
| 1290 | 4.872 | 4.302 | 3.791 | 3.314 | 2.854 | 2.145 | 1.750 |
| 1300 | 4.862 | 4.289 | 3.780 | 3.304 | 2.848 | 2.135 | 1.744 |
| 1310 | 4.852 | 4.276 | 3.769 | 3.294 | 2.842 | 2.126 | 1.737 |
| 1320 | 4.842 | 4.263 | 3.758 | 3.283 | 2.835 | 2.116 | 1.731 |
| 1330 | 4.832 | 4.250 | 3.747 | 3.273 | 2.829 | 2.106 | 1.725 |
| 1340 | 4.822 | 4.237 | 3.736 | 3.263 | 2.822 | 2.097 | 1.719 |
| 1350 | 4.812 | 4.224 | 3.725 | 3.253 | 2.816 | 2.087 | 1.712 |

TABLE 120 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % $UF_4$) | $a$ | $b \cdot 10_4$ | Stand. dev. [98] |
|---|---|---|---|
| 0.0 | 2.555 | −6.241 | 0.00276 |
| 7.5 | 3.387 | −9.629 | 0.0206 |
| 20.0 | 3.681 | −6.407 | 0.00800 |
| 30.0 | 4.618 | −10.110 | 0.00398 |
| 40.0 | 5.218 | −11.060 | 0.0254 |
| 50.0 | 5.974 | −12.960 | 0.0429 |
| 60.0 | 6.174 | −10.090 | 0.0201 |

Reference: [98]. Data reported in equation form.

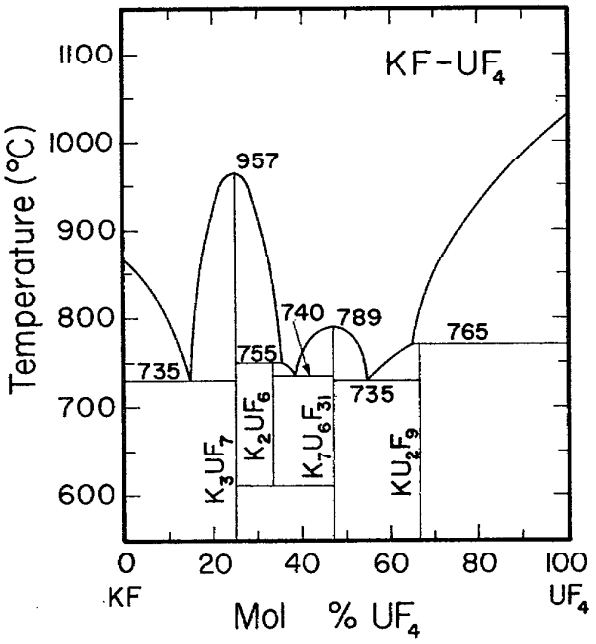


FIGURE 33. Temperature-composition phase diagram for KF-$UF_4$. R. E. Thoma, H. Insley, B. S. Landau, H. A. Friedman, and W. R. Grimes, J. Amer. Ceram. Soc. **41**, 538 (1958).

## KF-$YF_3$

### Electrical Conductance

The recommended values in table 123 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [87].

TABLE 121 A. Investigations critically re-examined

| Ref. | $YF_3$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0, 7.5, 17.5, 30.0, 42.5, 52.5 | 1123–1343 |

TABLE 121 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $YF_3$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 87 | 1 | 3 | 0 | 3.5 | (1280) | 4.5 | (1140) |

TABLE 121 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

Comment: The specific conductance values measured in reference [87] were reported reproducible to ±1 percent. The precision of the measurements was ±3 percent. The measured resistance was found to be independent of frequency over the range 20 to 20,000 hertz.

### Density

The recommended values in tables 124, 125 are based on the work of Meaker and Porter (Archimedean method) [98].

TABLE 122 A. Investigations critically re-examined

| Ref. | $YF_3$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0–53 (graphical) | 1273 |
| 98 | 0, 7.5, 17.5, 30.0, 42.5, 52.5 | 1073–1353 |

TABLE 122 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $YF_3$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 98 | 1 | 3 | 0 | −3.1 | (1140–1280) | | |

TABLE 122 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [87, 98] | Molten KCl [87, 98]] |

Comment: Brief remarks concerning reference [98] are given under the system $CaF_2$–LiF.

Density values [98] were reported in the form of linear temperature-dependent equations with standard deviations in the range: $2.13\times10^{-3}$ gcm$^{-3}$ (7.5 mol % $YF_3$) to $6.29\times10^{-3}$ gcm$^{-3}$ (52.5 mol % $YF_3$).

## Melt Preparation and Purification

The method used by Porter et al. [87, 98] is described under the system $CaF_2$-LiF. Yttrium fluoride contained less than 0.1 weight-percent of metallic impurities.

TABLE 123 a. KF-$YF_3$: Electrical conductance

Specific conductance: Numerical values (ohm$^{-1}$ cm$^{-1}$)

| | Mol percent $YF_3$ | | | | | |
|---|---|---|---|---|---|---|
| $T$ | 52.5 | 42.5 | 30.0 | 17.5 | 7.5 | 0.0 |
| 1130 | | | | | 2.88 | |
| 1140 | | | | | 2.91 | 3.74 |
| 1150 | 1.20 | | | | 2.94 | 3.77 |
| 1160 | 1.24 | | | | 2.96 | 3.80 |
| 1170 | 1.28 | | | | 2.99 | 3.83 |
| 1180 | 1.31 | | | | 3.02 | 3.86 |
| 1190 | 1.35 | | | | 3.05 | 3.89 |
| 1200 | 1.39 | | | | 3.08 | 3.92 |
| 1210 | 1.43 | | | 2.27 | 3.10 | 3.95 |
| 1220 | 1.46 | | | 2.30 | 3.13 | 3.98 |
| 1230 | 1.50 | | 1.51 | 2.33 | 3.16 | 4.01 |
| 1240 | 1.54 | 1.42 | 1.54 | 2.36 | 3.19 | 4.03 |
| 1250 | 1.57 | 1.45 | 1.56 | 2.39 | 3.22 | 4.06 |
| 1260 | 1.61 | 1.48 | 1.59 | 2.42 | 3.24 | 4.09 |
| 1270 | 1.65 | 1.51 | 1.61 | 2.45 | 3.27 | 4.12 |
| 1280 | 1.69 | 1.54 | 1.64 | 2.48 | 3.30 | 4.15 |
| 1290 | 1.72 | 1.57 | 1.67 | 2.51 | 3.33 | 4.18 |
| 1300 | 1.76 | 1.60 | 1.69 | 2.54 | 3.36 | 4.21 |
| 1310 | 1.80 | 1.62 | 1.72 | 2.57 | 3.38 | 4.24 |
| 1320 | 1.83 | 1.65 | 1.74 | 2.60 | 3.41 | 4.27 |
| 1330 | 1.87 | 1.68 | 1.77 | 2.63 | 3.44 | 4.30 |
| 1340 | 1.91 | 1.71 | 1.79 | 2.66 | 3.47 | 4.33 |

TABLE 123 b. Temperature-dependent equations

$\kappa = a + bT$ (ohm$^{-1}$ cm$^{-1}$)

| Comp. (mol % $YF_3$) | $a$ | $b\cdot10^3$ | Stand. deviation [87] |
|---|---|---|---|
| 0.0 | 0.388 | 2.940 | 0.0179 |
| 7.5 | −0.291 | 2.805 | 0.0325 |
| 17.5 | −1.362 | 3.000 | 0.0223 |
| 30.0 | −1.633 | 2.557 | 0.02557 |
| 42.5 | −2.096 | 2.839 | 0.0292 |
| 52.5 | −3.070 | 3.715 | 0.0232 |

Reference: [87]. Data reported in equation form.

TABLE 124 a. $KF\text{-}YF_3$: Density

Numerical values ($gcm^{-3}$)

Mol percent $YF_3$

| $T$ | 50 | 45 | 40 | 35 | 30 | 25 | 20 | 15 | 10 | 5 | 0 | 43 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1080 | | | | | | | | | | 1.984 | | |
| 1095 | | | | | | | | | 2.081 | 1.975 | | |
| 1110 | | | | | | | | | 2.072 | 1.966 | | |
| 1125 | | | | | | | | | 2.063 | 1.957 | | |
| 1140 | | | | | | | | 2.159 | 2.053 | 1.947 | 1.841 | |
| 1155 | | | | | | | | 2.150 | 2.044 | 1.938 | 1.831 | |
| 1170 | 2.942 | | | | | | | 2.141 | 2.035 | 1.929 | 1.822 | |
| 1185 | 2.932 | 2.806 | | | | | 2.238 | 2.131 | 2.026 | 1.920 | 1.813 | |
| 1200 | 2.923 | 2.797 | | | | | 2.229 | 2.122 | 2.016 | 1.911 | 1.804 | 2.748 |
| 1215 | 2.913 | 2.787 | 2.666 | | | 2.327 | 2.219 | 2.113 | 2.007 | 1.901 | 1.795 | 2.738 |
| 1230 | 2.903 | 2.777 | 2.657 | 2.540 | 2.428 | 2.318 | 2.210 | 2.104 | 1.998 | 1.892 | 1.786 | 2.729 |
| 1245 | 2.893 | 2.768 | 2.647 | 2.531 | 2.418 | 2.308 | 2.201 | 2.094 | 1.989 | 1.883 | 1.777 | 2.719 |
| 1260 | 2.884 | 2.758 | 2.638 | 2.521 | 2.409 | 2.299 | 2.191 | 2.085 | 1.980 | 1.874 | 1.768 | 2.709 |
| 1275 | 2.874 | 2.748 | 2.628 | 2.512 | 2.399 | 2.289 | 2.182 | 2.076 | 1.970 | 1.865 | 1.759 | 2.700 |
| 1290 | 2.864 | 2.739 | 2.618 | 2.502 | 2.390 | 2.280 | 2.173 | 2.067 | 1.961 | 1.856 | 1.750 | 2.690 |
| 1305 | 2.855 | 2.729 | 2.609 | 2.493 | 2.380 | 2.271 | 2.163 | 2.057 | 1.952 | 1.847 | 1.741 | 2.681 |
| 1320 | 2.845 | 2.720 | 2.599 | 2.483 | 2.371 | 2.261 | 2.154 | 2.048 | 1.943 | 1.838 | 1.732 | 2.671 |
| 1335 | 2.835 | 2.710 | 2.590 | 2.474 | 2.362 | 2.252 | 2.145 | 2.039 | 1.934 | 1.829 | 1.723 | 2.661 |
| 1350 | 2.826 | 2.700 | 2.580 | 2.464 | 2.352 | 2.243 | 2.136 | 2.030 | 1.925 | 1.820 | 1.714 | 2.652 |

TABLE 124 b. Two-dimensional equation and statistical parameters

$\rho = a + bT + cC + dC^2 + eC^3 + fCT^2$ ($gcm^{-3}$)

| $a$ | $b \cdot 10^4$ | $c \cdot 10^3$ | $d \cdot 10^4$ | $e \cdot 10^7$ | $f \cdot 10^{10}$ | Max. percent departure | Stand. error of est. |
|---|---|---|---|---|---|---|---|
| 5.44520 | −6.90657 | −4.49311 | 2.59050 | −9.59873 | 3.48411 | −0.43 (1343.2K, 82.5 mol % KF) | 0.003 |

Reference: [98]. Data reported in equation form.
$C$ = mol percent KF.

TABLE 125 a. KF-$YF_3$: Density

Numerical values ($gcm^{-3}$)

Mol percent $YF_3$

| $T$ | 52.5 | 42.5 | 30.0 | 17.5 | 7.5 | 0.0 |
|---|---|---|---|---|---|---|
| 1080 | | | | | 2.037 | |
| 1095 | | | | | 2.028 | |
| 1110 | | | | | 2.018 | |
| 1125 | | | | | 2.009 | |
| 1140 | | | | | 2.000 | 1.844 |
| 1155 | | | | | 1.990 | 1.834 |
| 1170 | 3.008 | | | 2.190 | 1.981 | 1.825 |
| 1185 | 2.998 | | | 1.182 | 1.971 | 1.815 |
| 1200 | 2.988 | 2.738 | | 1.174 | 1.962 | 1.806 |
| 1215 | 2.978 | 2.728 | | 2.165 | 1.952 | 1.797 |
| 1230 | 2.968 | 2.718 | 2.425 | 2.157 | 1.943 | 1.787 |
| 1245 | 2.959 | 2.708 | 2.416 | 2.149 | 1.934 | 1.778 |
| 1260 | 2.949 | 2.698 | 2.407 | 2.141 | 1.924 | 1.769 |
| 1275 | 2.939 | 2.688 | 2.398 | 2.133 | 1.915 | 1.759 |
| 1290 | 2.929 | 2.677 | 2.389 | 2.125 | 1.905 | 1.750 |
| 1305 | 2.919 | 2.667 | 2.380 | 2.117 | 1.896 | 1.741 |
| 1320 | 2.909 | 2.657 | 2.370 | 2.108 | 1.886 | 1.731 |
| 1335 | 2.900 | 2.647 | 2.361 | 2.100 | 1.877 | 1.722 |
| 1350 | 2.890 | 2.637 | 3.352 | 2.092 | 1.867 | 1.712 |

TABLE 125 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % $YF_3$) | $a$ | $b \cdot 10^4$ | Stand. dev. [98] |
|---|---|---|---|
| 0.0 | 2.555 | −6.241 | 0.00276 |
| 7.5 | 2.717 | −6.293 | 0.00213 |
| 17.5 | 2.825 | −5.429 | 0.00413 |
| 30.0 | 3.177 | −6.110 | 0.00263 |
| 42.5 | 3.551 | −6.772 | 0.00300 |
| 52.5 | 3.775 | −6.558 | 0.00629 |

Reference: [98]. Data reported in equation form.

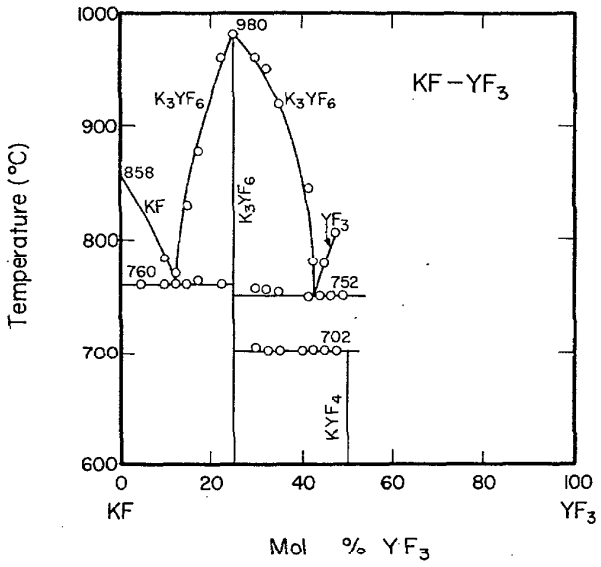


FIGURE 34. Temperature-composition phase diagram for KF-$YF_3$. G. A. Bukhalova and E. P. Babaeva, Russ. J. Inorg. Chem. **11**, 350 (1966).

## $KF\text{-}ZrF_4$

### Electrical Conductance

The recommended values in table 130 are based on the work of Sheiko (classical ac technique) **[107]**.

TABLE 126 A. Investigations critically re-examined

| Ref. | $ZrF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| **107** | 0–33.3 | 1233 |

TABLE 126 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $ZrF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| **107** | 1 | 3 | 0 | 51.6 | (1233) | | |

TABLE 126 C. Cell materials and electrodes

| Cell material | Electrodes |
|---|---|
| Porcelain crucible [107] | Pt [107] |

## Density

The recommended values in table 131 are based on the work of Sheiko (Archimedean method) [107].

TABLE 127 A. Investigations critically re-examined

| Ref. | $ZrF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 107 | 0–33.3 | 1233 |

TABLE 127 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $ZrF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 107 | 1 | 3 | 0 | −2.3 | (1233) | | |

Comment: Sheiko [107] used a platinum sphere as the float and used a platinum cup to contain the melt.

## Viscosity

The recommended values in table 132 are based on the work of Sheiko (oscillating sphere method) [107].

TABLE 128 A. Investigations critically re-examined

| Ref. | $ZrF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 107 | 0–33.3 | 1253 |

Comment: Sheiko [107] used a platinum sphere as the oscillating bob.

## Surface Tension

The recommended values in table 133 are based on the work of Sheiko (maximum bubble pressure method) [107].

TABLE 129 A. Investigations critically re-examined

| Ref. | $ZrF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 107 | 0–33.3 | 1233 |

TABLE 129 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $ZrF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 107 | 1 | 3 | 0 | 0.4 | (1233) | | |

TABLE 130. $KF$-$ZrF_4$: Electrical conductance

Specific conductance: Numerical values ($ohm^{-1}$ $cm^{-1}$)

Mol percent $ZrF_4$

| $T$ | 33.3 | 32.1 | 30.8 | 30.0 | 29.2 | 28.6 | 27.3 | 25.0 | 22.2 | 19.9 | 16.7 | 14.3 | 8.3 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1233.2 | 2.61 | 2.68 | 2.81 | 2.96 | 3.05 | 3.14 | 3.37 | 3.81 | 3.94 | 4.28 | 4.67 | 4.84 | 5.30 | 5.86 |

Reference: [107]. Due to limited data the experimental values are given.

TABLE 131. $KF-ZrF_4$: Density

Numerical values ($gcm^{-3}$)

Mol percent $ZrF_4$

| $T$ | 33.3 | 32.1 | 30.8 | 29.2 | 27.3 | 25.0 | 22.2 | 18.8 | 14.3 | 8.3 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1233.2 | 2.220 | 2.190 | 2.173 | 2.168 | 2.139 | 2.129 | 2.114 | 2.086 | 2.043 | 1.952 | 1.800 |

Reference: [107]. Due to limited data the experimental values are given.

TABLE 132. $KF-ZrF_4$: Viscosity

Numerical values (cp)

Mol percent $ZrF_4$

| $T$ | 33.3 | 32.1 | 30.2 | 29.2 | 27.3 | 25.0 | 22.2 | 18.8 | 14.3 | 8.3 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1253.2 | 2.28 | 2.24 | 2.22 | 2.19 | 2.18 | 2.15 | 2.01 | 1.91 | 1.79 | 1.69 | 1.59 |

Reference: [107]. Due to limited data the experimental values are given.

TABLE 133. $KF-ZrF_4$: Surface tension

Numerical values (dyn $cm^{-1}$)

Mol percent $ZrF_4$

| $T$ | 33.3 | 32.1 | 30.8 | 29.2 | 27.3 | 25.0 | 22.2 | 18.8 | 8.3 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1233.3 | 93.2 | 98.4 | 99.7 | 102.8 | 104.5 | 109.6 | 120.0 | 125.9 | 133.3 | 135.7 |

Reference: [107]. Due to limited data the experimental values are given.

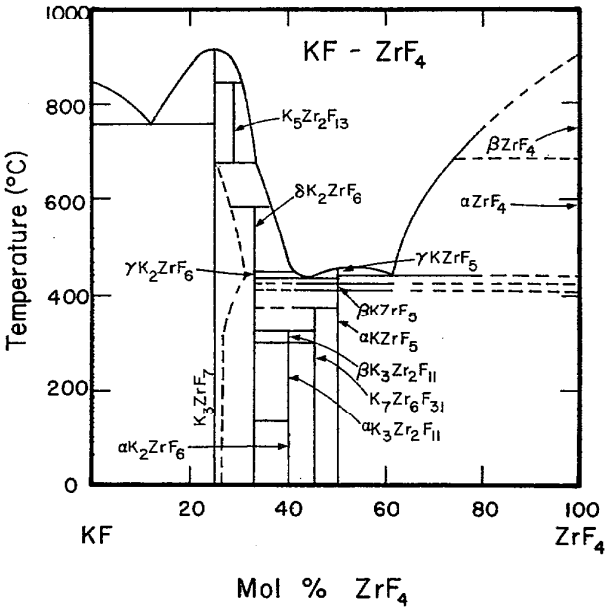


FIGURE 35. Temperature-composition phase diagram for KF-$ZrF_4$.
A. V. Novoselova, Yu. M. Korenev, and Yu. D. Simanov, Dokl. Akad. Nauk S.S.S.R., **139** [4], 893 (1961).
C. J. Barton, H. Insley, R. E. Metcalf, R. E. Thoma and W. R. Grimes, ORNL-2548, pg. 56 (1959).

## $LaF_3$-LiF

### Electrical Conductance

The recommended values in table 136 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [87].

TABLE 134 A. Investigations critically re-examined

| Ref. | LiF (mol %) | Temp. range (*T*) |
|---|---|---|
| 87 | 67.55–100 | 1143–1343 |

TABLE 134 B. Comparisons with previous recommendations

| Ref. | Recommended value | | LiF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (*T*) | % (max) | (*T*) |
| 87 | 1 | 2 | 100 | 5.1 | (1150) | 8.2 | (1310) |

TABLE 134 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

Comment: Brief remarks concerning reference [87] are discussed under the system $CaF_2$–LiF.

### Density

The recommended values in table 137 are based on the work of Meaker and Porter (Archimedean method) [98].

TABLE 135 A. Investigations critically re-examined

| Ref. | LiF (mol %) | Temp. range (*T*) |
|---|---|---|
| 87 | 75–100 (graphical) | 1273 |
| 98 | 75, 80, 85, 90, 95, 100 | 1103–1353 |

TABLE 135 B. Comparisons with previous recommendations

| Ref. | Recommended value | | LiF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (*T*) | % (max) | (*T*) |
| 98 | 1 | 2 | 100 | −4.5 | (1310) | −5.6 | (1150) |

TABLE 135 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [87, 98] | Molten KCl [87, 98] |

Comment: Brief remarks concerning reference [98] are given under the system $CaF_2$–LiF.

Density values [98] were reported in the form of linear temperature-dependent equations with standard deviations in the range: $2.00 \times 10^{-3}$ gcm$^{-3}$ (75 mol % LiF) to $7.05 \times 10^{-3}$ gcm$^{-3}$ (100 mol % LiF).

### Melt Preparation and Purification

The method of salt purification used by Porter et al. [87, 98] is described under the system $CaF_2$-LiF.

Lanthanum fluoride contained less than 0.1 weight-percent of metallic impurities.

TABLE 136 a. $LaF_3$-LiF: Electrical conductance

Specific conductance: Numerical values ($ohm^{-1}$ $cm^{-1}$)

Mol percent LiF

| $T$ | 100.0 | 95.0 | 90.0 | 85.0 | 80.0 | 75.0 | 71.0 | 67.55 |
|---|---|---|---|---|---|---|---|---|
| 1150 | 9.10 | | | | | | | |
| 1160 | 9.16 | | | | 6.22 | | 4.98 | |
| 1170 | 9.22 | | 7.47 | | 6.27 | | 5.06 | |
| 1180 | 9.27 | 8.45 | 7.54 | | 6.32 | | 5.15 | |
| 1190 | 9.33 | 8.51 | 7.60 | 7.08 | 6.37 | 5.51 | 5.23 | |
| 1200 | 9.39 | 8.56 | 7.66 | 7.13 | 6.41 | 5.57 | 5.32 | |
| 1210 | 9.45 | 8.62 | 7.73 | 7.18 | 6.46 | 5.63 | 5.40 | |
| 1220 | 9.51 | 8.67 | 7.79 | 7.23 | 6.51 | 5.69 | 5.49 | |
| 1230 | 9.57 | 8.73 | 7.85 | 7.28 | 6.56 | 5.75 | 5.57 | |
| 1240 | 9.62 | 8.78 | 7.92 | 7.33 | 6.60 | 5.81 | 5.66 | |
| 1250 | 9.68 | 8.84 | 7.98 | 7.38 | 6.65 | 5.87 | 5.74 | |
| 1260 | 9.74 | 8.90 | 8.04 | 7.42 | 6.70 | 5.94 | 5.83 | 5.43 |
| 1270 | 9.80 | 8.95 | 8.11 | 7.47 | 6.75 | 6.00 | 5.91 | 5.52 |
| 1280 | 9.86 | 9.01 | 8.17 | 7.52 | 6.79 | 6.06 | 6.00 | 5.60 |
| 1290 | 9.92 | 9.06 | 8.23 | 7.57 | 6.84 | 6.12 | 6.08 | 5.68 |
| 1300 | 9.97 | 9.12 | 8.30 | 7.62 | 6.89 | 6.18 | 6.17 | 5.76 |
| 1310 | 10.03 | 9.17 | 8.36 | 7.67 | 6.94 | 6.24 | 6.25 | 5.84 |
| 1320 | 10.90 | 9.23 | 8.42 | 7.72 | 6.98 | 6.30 | 6.34 | 5.92 |
| 1330 | 10.15 | 9.29 | 8.49 | 7.77 | 7.03 | 6.36 | 6.42 | 6.01 |
| 1340 | 10.21 | 9.34 | 8.55 | 7.82 | 7.08 | 6.42 | 6.51 | 6.09 |

TABLE 136 b. Temperature-dependent equations

$\kappa = a + bT$ ($ohm^{-1}$ $cm^{-1}$)

| Comp. (mol % LiF) | $a$ | $b \cdot 10^3$ | Stand. deviation [87] |
|---|---|---|---|
| 67.55 | −4.872 | 8.179 | 0.0489 |
| 71.0 | −4.898 | 8.513 | 0.0635 |
| 75.0 | −1.775 | 6.119 | 0.0090 |
| 80.0 | 0.698 | 4.762 | 0.0405 |
| 85.0 | 1.255 | 4.896 | 0.0182 |
| 90.0 | 0.054 | 6.340 | 0.0423 |
| 95.0 | 1.884 | 5.565 | 0.0270 |
| 100.0 | 2.395 | 5.830 | 0.050 |

Reference: [87]. Data reported in equation form.

TABLE 137 a. $LaF_3$-LiF: Density

Numerical values ($gcm^{-3}$)

Mol percent LiF

| $T$ | 100.0 | 95.0 | 90.0 | 85.0 | 80.0 | 75.0 |
|---|---|---|---|---|---|---|
| 1110 | | | | 2.761 | | |
| 1120 | | | | 2.754 | | |
| 1130 | 1.699 | | | 2.748 | 3.004 | 3.177 |
| 1140 | 1.695 | 2.075 | | 2.741 | 2.998 | 3.171 |
| 1150 | 1.692 | 2.071 | | 2.734 | 2.991 | 3.166 |
| 1160 | 1.689 | 2.068 | | 2.728 | 2.985 | 3.160 |
| 1170 | 1.685 | 2.064 | | 2.721 | 2.978 | 3.155 |
| 1180 | 1.682 | 2.061 | 2.431 | 2.714 | 2.972 | 3.149 |
| 1190 | 1.679 | 2.057 | 2.428 | 2.708 | 2.965 | 3.144 |
| 1200 | 1.675 | 2.053 | 2.425 | 2.701 | 2.959 | 3.138 |
| 1210 | 1.672 | 2.050 | 2.422 | 2.694 | 2.952 | 3.133 |
| 1220 | 1.669 | 2.046 | 2.419 | 2.688 | 2.946 | 3.127 |
| 1230 | 1.666 | 2.042 | 2.415 | 2.681 | 2.939 | 3.122 |
| 1240 | 1.662 | 2.039 | 2.412 | 2.674 | 2.933 | 3.116 |
| 1250 | 1.659 | 2.035 | 2.409 | 2.668 | 2.926 | 3.111 |
| 1260 | 1.656 | 2.031 | 2.406 | 2.661 | 2.920 | 3.105 |
| 1270 | 1.652 | 2.028 | 2.403 | 2.654 | 2.913 | 3.100 |
| 1280 | 1.649 | 2.024 | 2.400 | 2.648 | 2.907 | 3.094 |
| 1290 | 1.646 | 2.020 | 2.397 | 2.641 | 2.900 | 2.089 |
| 1300 | 1.642 | 2.017 | 2.394 | 2.634 | 2.894 | 3.083 |
| 1310 | 1.639 | 2.013 | 2.391 | 2.628 | 2.887 | 3.078 |
| 1320 | 1.636 | 2.009 | 2.387 | 2.621 | 2.881 | 3.072 |
| 1330 | 1.632 | 2.006 | 2.384 | 2.614 | 2.874 | 3.067 |
| 1340 | 1.629 | 2.002 | 2.381 | 2.608 | 2.868 | 3.061 |
| 1350 | 1.626 | 1.999 | 2.378 | 2.601 | 2.861 | 3.056 |

TABLE 137 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % LiF) | $a$ | $b \cdot 10^4$ | Stand. dev. [98] |
|---|---|---|---|
| 75.0 | 3.799 | −5.507 | 0.00200 |
| 80.0 | 3.737 | −6.486 | 0.00334 |
| 85.0 | 3.500 | −6.658 | 0.00383 |
| 90.0 | 2.799 | −3.118 | 0.00500 |
| 95.0 | 2.491 | −3.648 | 0.00580 |
| 100.0 | 2.074 | −3.321 | 0.00705 |

Reference: [98]. Data reported in equation form.

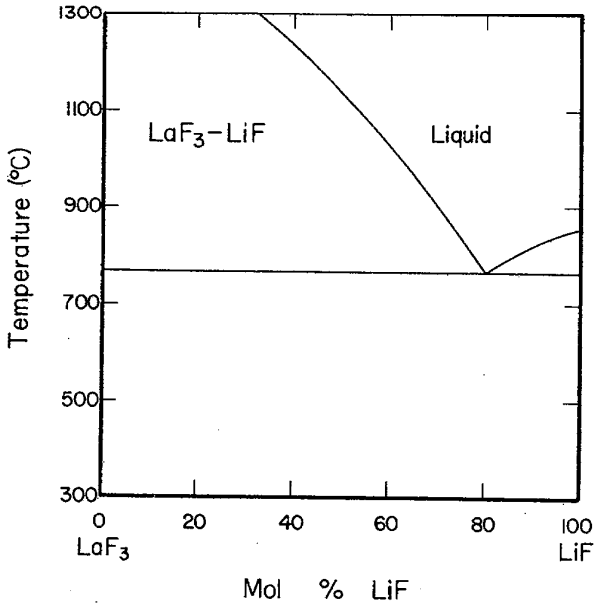


FIGURE 36. Temperature-composition phase diagram for $LaF_3$-LiF. R. E. Thoma, Progress in Science and Technology of the Rare Earths, Vol. 2, p. 110, Pergamon Press, N.Y. 1966.

## $LaF_3$-NaF

### Electrical Conductance

The recommended values in table 140 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [87].

TABLE 138 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range (*T*) |
|---|---|---|
| 87 | 60, 70, 80, 90, 100 | 1053–1343 |

TABLE 138 B. Comparisons with previous recommendations

| Ref. | Recommended value | | NaF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (*T*) | % (max) | (*T*) |
| 87 | 1 | 3 | 0 | 5.0 | (1300) | 7.4 | (1340) |

TABLE 138 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

Comment: Brief remarks concerning reference [87] are discussed under the system $CaF_2$–LiF.

### Density

The recommended values in tables 141, 142 are based on the work of Meaker and Porter (Archimedean method) [98].

TABLE 139 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range (*T*) |
|---|---|---|
| 87 | 60–100 (graphical) | 1273 |
| 98 | 60, 70, 80, 90, 100 | 1073–1353 |

TABLE 139 B. Comparisons with previous recommendations

| Ref. | Recommended value | | NaF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (*T*) | % (max) | (*T*) |
| 98 | 1 | 3 | 0 | −2.2 | (1270) | −2.5 | (1350) |

TABLE 139 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [87, 98] | Molten KCl [87, 98] |

Comment: Brief remarks concerning reference [98] are given under the system $CaF_2$–LiF.

Density values [98] were reported in the form of linear temperature-dependent equations with standard deviations in the range: $2.39\times10^{-3}$ gcm$^{-3}$ (100 mol % NaF) to $10.2\times10^{-3}$ gcm$^{-3}$ (60 mol % NaF).

### Melt Preparation and Purification

The method of salt purification used by Porter et al. [87, 98] is described under the system $CaF_2$-LiF.

Lanthanum fluoride contained less than 0.1 weight-percent of metallic impurities.

TABLE 140 a. $LaF_3$-NaF: Electrical conductance

Specific conductance: Numerical values ($ohm^{-1}$ $cm^{-1}$)

Mol percent NaF

| $T$ | 100.0 | 90.0 | 80.0 | 70.0 | 60.0 |
|---|---|---|---|---|---|
| 1060 | | | | 2.33 | |
| 1070 | | | | 2.39 | |
| 1080 | | | | 2.45 | |
| 1090 | | | | 2.51 | |
| 1100 | | | | 2.57 | |
| 1110 | | | | 2.63 | |
| 1120 | | | | 2.69 | |
| 1130 | | | | 2.76 | |
| 1140 | | | | 2.82 | |
| 1150 | | | | 2.88 | |
| 1160 | | | | 2.94 | |
| 1170 | | | 3.34 | 3.00 | |
| 1180 | | | 3.39 | 3.06 | |
| 1190 | | | 3.44 | 3.12 | |
| 1200 | | | 3.49 | 3.18 | |
| 1210 | | | 3.54 | 3.24 | 2.89 |
| 1220 | | | 3.59 | 3.30 | 2.95 |
| 1230 | | | 3.64 | 3.36 | 3.00 |
| 1240 | | 4.26 | 3.69 | 3.43 | 3.05 |
| 1250 | | 4.31 | 3.74 | 3.49 | 3.11 |
| 1260 | | 4.35 | 3.79 | 3.55 | 3.16 |
| 1270 | | 4.40 | 3.84 | 3.61 | 3.21 |
| 1280 | | 4.45 | 3.89 | 3.67 | 3.27 |
| 1290 | | 4.49 | 3.94 | 3.73 | 3.32 |
| 1300 | | 4.54 | 3.99 | 3.79 | 3.38 |
| 1310 | 5.33 | 4.59 | 4.04 | 3.85 | 3.43 |
| 1320 | 5.39 | 4.63 | 4.08 | 3.91 | 3.48 |
| 1330 | 5.44 | 4.68 | 4.13 | 3.97 | 3.54 |
| 1340 | 5.50 | 4.73 | 4.18 | 4.03 | 3.59 |

TABLE 140 b. Temperature-dependent equations

$\kappa = a + bT$ ($ohm^{-1}$ $cm^{-1}$)

| Comp. (mol % NaF) | $a$ | $b \cdot 10^3$ | Stand. deviation [87] |
|---|---|---|---|
| 60.0 | −3.561 | 5.334 | 0.0142 |
| 70.0 | −4.123 | 6.087 | 0.0143 |
| 80.0 | −2.443 | 4.945 | 0.0240 |
| 90.0 | −1.559 | 4.691 | 0.0300 |
| 100.0 | −2.060 | 5.640 | 0.0660 |

Reference: [87]. Data reported in equation form.

TABLE 141 a. $LaF_3$-NaF: Density

Numerical values ($gcm^{-3}$)

Mol percent NaF

| $T$ | 100 | 95 | 90 | 85 | 80 | 75 | 70 | 65 | 60 | 72 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1080 | | | | | | | 3.347 | | | |
| 1095 | | | | | | | 3.336 | 3.502 | | 3.264 |
| 1110 | | | | | | 3.140 | 3.325 | 3.491 | | 3.253 |
| 1125 | | | | | | 3.129 | 3.314 | 3.479 | | 3.242 |
| 1140 | | | | | | 3.118 | 3.303 | 3.468 | | 3.231 |
| 1155 | | | | | 2.907 | 3.107 | 3.291 | 3.456 | | 3.220 |
| 1170 | | | | | 2.896 | 3.097 | 3.280 | 3.444 | | 3.209 |
| 1185 | | | | | 2.885 | 3.086 | 3.269 | 3.433 | | 3.198 |
| 1200 | | | | 2.660 | 2.875 | 3.075 | 3.258 | 3.421 | | 3.187 |
| 1215 | | | | 2.650 | 2.864 | 3.064 | 3.247 | 3.410 | 3.551 | 3.176 |
| 1230 | | | | 2.640 | 2.854 | 3.053 | 3.235 | 3.398 | 3.539 | 3.165 |
| 1245 | | | 2.403 | 2.629 | 2.843 | 3.042 | 3.224 | 3.387 | 3.527 | 3.154 |
| 1260 | | 2.156 | 2.393 | 2.619 | 2.833 | 3.032 | 3.213 | 3.375 | 3.515 | 3.143 |
| 1275 | 1.903 | 2.146 | 2.382 | 2.608 | 2.822 | 3.021 | 3.202 | 3.363 | 3.503 | 3.132 |
| 1290 | 1.893 | 2.136 | 2.372 | 2.598 | 2.811 | 3.010 | 3.191 | 3.352 | 3.491 | 3.121 |
| 1305 | 1.882 | 2.126 | 2.362 | 2.588 | 2.801 | 2.999 | 3.180 | 3.340 | 3.479 | 3.110 |
| 1320 | 1.872 | 2.116 | 2.352 | 2.577 | 2.790 | 2.988 | 3.168 | 3.329 | 3.467 | 3.099 |
| 1335 | 1.862 | 2.106 | 2.342 | 2.567 | 2.780 | 2.977 | 3.157 | 3.317 | 3.455 | 3.088 |
| 1350 | 1.852 | 2.096 | 2.331 | 2.557 | 2.769 | 2.966 | 3.146 | 3.306 | 3.443 | 3.077 |

TABLE 141 b. Two-dimensional equation and statistical parameters

$\rho = a + bT + cC + dC^3 + eTC^2$ (gcm$^{-3}$)

| $a$ | $b \cdot 10^4$ | $c \cdot 10^2$ | $d \cdot 10^6$ | $e \cdot 10^8$ | Max. percent departure | Stand. error of est. |
|---|---|---|---|---|---|---|
| 2.75981 | −6.72268 | 4.93313 | −3.25825 | −8.07650 | −0.43 (1338.2 K, 10 mol % $LaF_3$) | 0.004 |

Reference: [98]. Data reported in equation form.
$C$=mol percent $LaF_3$.

TABLE 142 a. $LaF_3$-NaF: Density

Numerical values (gcm$^{-3}$)

Mol percent NaF

| $T$ | 100.0 | 90.0 | 80.0 | 70.0 | 60.0 |
|---|---|---|---|---|---|
| 1080 | | | | 3.347 | |
| 1095 | | | | 3.336 | |
| 1110 | | | | 3.325 | |
| 1125 | | | | 3.314 | |
| 1140 | | | | 3.303 | |
| 1155 | | | 2.910 | 3.292 | |
| 1170 | | | 2.898 | 3.281 | |
| 1185 | | | 2.886 | 3.270 | |
| 1200 | | | 2.875 | 3.259 | |
| 1215 | | | 2.863 | 3.248 | 3.544 |
| 1230 | | | 2.852 | 3.237 | 3.533 |
| 1245 | | 2.406 | 2.840 | 3.226 | 3.523 |
| 1260 | | 2.397 | 2.829 | 3.215 | 3.512 |
| 1275 | 1.898 | 2.388 | 2.817 | 3.204 | 3.502 |
| 1290 | 1.889 | 2.379 | 2.805 | 3.193 | 3.491 |
| 1305 | 1.879 | 2.370 | 2.794 | 3.181 | 3.481 |
| 1320 | 1.870 | 2.360 | 2.782 | 3.170 | 3.470 |
| 1335 | 1.861 | 2.351 | 2.771 | 3.159 | 3.459 |
| 1350 | 1.852 | 2.342 | 2.759 | 3.148 | 3.449 |

TABLE 142 b. Temperature-dependent equations

$\rho = a + bT$ (gcm$^{-3}$)

| Comp. (mol % NaF) | $a$ | $b \cdot 10^4$ | Stand. dev. [98] |
|---|---|---|---|
| 60.0 | 4.400 | −7.045 | 0.0102 |
| 70.0 | 4.143 | −7.368 | 0.00525 |
| 80.0 | 3.802 | −7.726 | 0.00360 |
| 90.0 | 3.160 | −6.057 | 0.00353 |
| 100.0 | 2.682 | −6.151 | 0.00239 |

Reference: [98]. Data reported in equation form.

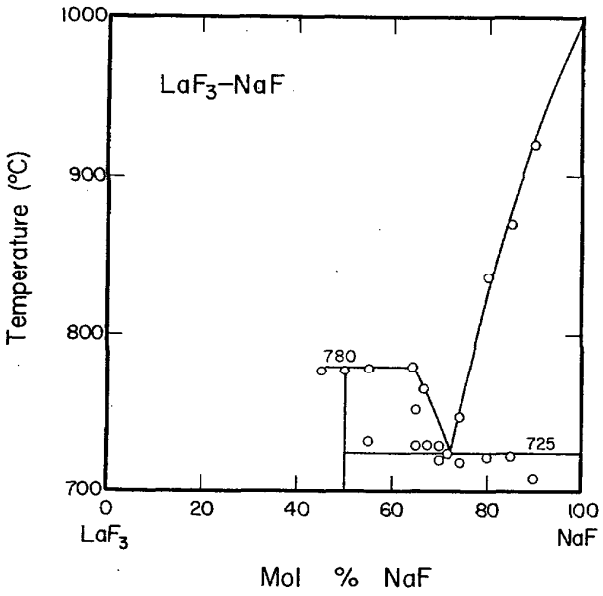


FIGURE 37. Temperature-composition phase diagram for $LaF_3$-Na
G. A. Bukhalova, E. P. Babaeva, and T. M. Khliyan,
Russ. J. Inorg. Chem. **10**, 1158 (1965).

## LiF-NaF

### Electrical Conductance

The recommended values in table 147 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [**87**].

TABLE 143 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0–100 | 1013–1343 |

TABLE 143 B. Comparisons with previous recommendations

| Ref. | Recommended value | | NaF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| 87 | 1 | 3 | 100 | 5.5 | (1310) | 8.3 | (1360) |
| 87 | 1 | 2 | 0 | 5.0 | (1160) | 6.8 | (1270) |

TABLE 143 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

Comment: Brief remarks concerning reference [87] are discussed under the system $CaF_2$–LiF.

## Density

The recommended values in table 148 are based on the work of Matiasovsky (Archimedean method) [75].

TABLE 144 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range (T) |
|---|---|---|
| 75 | 0–100 | 1123–1373 |
| 89 | 40 (eutectic, graphical) | 973–1173 |
| 88 | 40 (eutectic, graphical) | 1073, 1123 |
| 87 | 0–100 (graphical) | 1273 |
| 98 | 0–100 | 1023–1353 |

TABLE 144 B. Comparisons with previous recommendations

| Ref. | Recommended value | | NaF (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| 75 | 1 | 3 | 100 | −0.04 | (1323) | −0.24 | (1373) |
| 98 | 1 | 3 | 100 | −2.2 | (1280) | −2.5 | (1340) |
| 98 | 4.1 | 79 | 100 | −2.3 | (1323) | −2.4 | (1273) |
| 98 | 4.1 | 79 | 80 | −2.9 | (1233) | −3.7 | (1323) |
| 98 | 4.1 | 79 | 60 | 0.87 | (1123) | −3.7 | (1323) |
| 98 | 4.1 | 79 | 30 | 0.58 | (1123) | −3.1 | (1323) |
| 75 | 1 | 2 | 0 | 0.0 | (1323) | −0.19 | (1173) |
| 98 | 1 | 2 | 0 | −4.5 | (1310) | −5.6 | (1150) |
| 98 | 4.1 | 79 | 0 | −4.4 | (1323) | −5.5 | (1123) |

TABLE 144 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Spherical Pt sinker suspended by Pt wire, melt contained in Pt crucible [75] | Molten NaCl and KCl [75] |
| W bob suspended by a W or Mo wire, melt contained in Mo crucible [89, 88] | Molten KCl [87, 98] |
| Biconical Mo plummet suspended from Mo wire, melt contained in a graphite crucible [87, 98] | |

Comment: Matiasovsky [75] determined the volume of the density sinker in melts of NaCl and KCl over the temperature range 800–1050 ° C. The volumes differed by less than 0.2 percent. The reproducibility of measurements was better than 0.1 percent. No surface tension correction was applied.

Brief remarks concerning reference [98] are given under the system NaF–$ThF_4$. Density values were reported in the form of linear temperature-dependent equations with standard deviations in the range: $2.39\times10^{-3}$ gcm$^{-3}$ (100 mol % NaF) to $44.0\times10^{-3}$ gcm$^{-3}$ (38 mol % NaF).

## Viscosity

The recommended values in table 149 are based on the work of Cohen et al. (capillary and rotational cylinder method) [35].

TABLE 145 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range (T) |
|---|---|---|
| 35 | 40 | 973, 1073 |

## Surface Tension

The recommended values in figure 38 are based on the work of Mellors and Senderoff (maximum bubble pressure method) [89].

TABLE 146 A. Investigations critically re-examined

| Ref. | NaF (mol %) | Temp. range (T) |
|---|---|---|
| 89 | 40 (eutectic, graphical) | 973–1223 |
| 68 | 40 | 973–1073 |

Comment: Remarks concerning reference [89] are under the system KF-LiF.

### Melt Preparation and Purification

Salts used in references [88, 89] were ACS grade (obtained from Harshaw Chemical Company).

The procedure used by Porter et al. [87, 98] is discussed under the system $CaF_2$-LiF.

TABLE 147 a. LiF-NaF: Electrical conductance

Specific conductance: Numerical values ($ohm^{-1}$ $cm^{-1}$)

Mol percent NaF

| $T$ | 100.0 | 80.0 | 60.0 | 50.0 | 38.0 | 30.0 | 15.0 | 0.0 |
|---|---|---|---|---|---|---|---|---|
| 1020 | | | | | | 5.81 | | |
| 1030 | | | | | 5.54 | 5.87 | | |
| 1040 | | | | | 5.59 | 5.93 | | |
| 1050 | | | | | 5.65 | 5.99 | | |
| 1060 | | | | | 5.70 | 6.05 | 6.97 | |
| 1070 | | | | 5.40 | 5.76 | 6.11 | 7.04 | |
| 1080 | | | | 5.45 | 5.82 | 6.17 | 7.11 | |
| 1090 | | | | 5.51 | 5.87 | 6.24 | 7.18 | |
| 1100 | | | | 5.57 | 5.93 | 6.30 | 7.25 | |
| 1110 | | | | 5.62 | 5.98 | 6.36 | 7.32 | |
| 1120 | | | | 5.68 | 6.04 | 6.42 | 7.39 | |
| 1130 | | | 5.21 | 5.74 | 6.09 | 6.48 | 7.46 | |
| 1140 | | | 5.26 | 5.79 | 6.15 | 6.54 | 7.53 | |
| 1150 | | | 5.30 | 5.85 | 6.20 | 6.60 | 7.60 | 9.10 |
| 1160 | | | 5.34 | 5.90 | 6.26 | 6.66 | 7.67 | 9.16 |
| 1170 | | | 5.39 | 5.96 | 6.32 | 6.72 | 7.74 | 9.22 |
| 1180 | | 5.21 | 5.43 | 6.02 | 6.37 | 6.79 | 7.81 | 9.27 |
| 1190 | | 5.26 | 5.48 | 6.07 | 6.43 | 6.85 | 7.88 | 9.33 |
| 1200 | | 5.31 | 5.52 | 6.13 | 6.48 | 6.91 | 7.95 | 9.39 |
| 1210 | | 5.37 | 5.56 | 6.19 | 6.54 | 6.97 | 8.02 | 9.45 |
| 1220 | | 5.42 | 5.61 | 6.24 | 6.59 | 7.03 | 8.09 | 9.51 |
| 1230 | | 5.47 | 5.65 | 6.30 | 6.65 | 7.09 | 8.16 | 9.57 |
| 1240 | | 5.52 | 5.69 | 6.36 | 6.70 | 7.15 | 8.22 | 9.62 |
| 1250 | | 5.57 | 5.74 | 6.41 | 6.76 | 7.21 | 8.29 | 9.68 |
| 1260 | | 5.62 | 5.78 | 6.47 | 6.81 | 7.27 | 8.36 | 9.74 |
| 1270 | | 5.68 | 5.82 | 6.53 | 6.87 | 7.34 | 8.43 | 9.80 |
| 1280 | | 5.73 | 5.87 | 6.58 | 6.93 | 7.40 | 8.50 | 9.86 |
| 1290 | | 5.77 | 5.91 | 6.64 | 6.98 | 7.46 | 8.57 | 9.92 |
| 1300 | | 5.83 | 5.95 | 6.70 | 7.04 | 7.52 | 8.64 | 9.97 |
| 1310 | 5.33 | 5.88 | 6.00 | 6.75 | 7.09 | 7.58 | 8.71 | 10.03 |
| 1320 | 5.39 | 5.93 | 6.04 | 6.81 | 7.15 | 7.64 | 8.78 | 10.09 |
| 1330 | 5.44 | 5.99 | 6.08 | 6.87 | 7.20 | 7.70 | 8.85 | 10.15 |
| 1340 | 5.50 | 6.04 | 6.13 | 6.92 | 7.26 | 7.76 | 8.92 | 10.21 |

TABLE 147 b. Temperature-dependent equations

$\kappa = a + bT$ ($ohm^{-1}$ $cm^{-1}$)

| Comp. (mol % NaF) | $a \cdot 10^1$ | $b \cdot 10^3$ | Stand. dev. [87] |
|---|---|---|---|
| 0.0 | 23.95 | 5.830 | 0.0500 |
| 15.0 | −4.124 | 6.965 | 0.0301 |
| 30.0 | −4.307 | 6.115 | 0.0250 |
| 38.0 | −1.798 | 5.551 | 0.0301 |
| 50.0 | −6.533 | 5.653 | 0.0317 |
| 60.0 | 2.936 | 4.354 | 0.0246 |
| 80.0 | −8.848 | 5.166 | 0.0307 |
| 100.0 | −2.060 | 5.640 | 0.0660 |

Reference: [87]. Data reported in equation form.

TABLE 148 a. LiF-NaF: Density

Numerical values ($gcm^{-3}$)

Mol percent NaF

| $T$ | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 | 20 | 10 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1130 | | | | 1.964 | 1.949 | 1.924 | 1.905 | 1.875 | 1.822 | 1.856 | 1.800 |
| 1140 | | | | 1.959 | 1.944 | 1.919 | 1.900 | 1.869 | 1.816 | 1.848 | 1.795 |
| 1150 | | | | 1.954 | 1.938 | 1.913 | 1.894 | 1.864 | 1.811 | 1.841 | 1.791 |
| 1160 | | | | 1.948 | 1.932 | 1.907 | 1.888 | 1.859 | 1.806 | 1.833 | 1.786 |
| 1170 | | | | 1.943 | 1.927 | 1.902 | 1.883 | 1.854 | 1.801 | 1.826 | 1.781 |
| 1180 | | | | 1.937 | 1.921 | 1.896 | 1.877 | 1.848 | 1.796 | 1.818 | 1.777 |
| 1190 | | | | 1.932 | 1.916 | 1.891 | 1.872 | 1.843 | 1.791 | 1.811 | 1.772 |
| 1200 | | | | 1.926 | 1.910 | 1.885 | 1.866 | 1.838 | 1.786 | 1.803 | 1.767 |
| 1210 | | | | 1.921 | 1.905 | 1.879 | 1.861 | 1.832 | 1.781 | 1.796 | 1.763 |
| 1220 | | | | 1.916 | 1.899 | 1.874 | 1.855 | 1.827 | 1.776 | 1.788 | 1.758 |
| 1230 | | | 1.933 | 1.910 | 1.893 | 1.868 | 1.850 | 1.822 | 1.771 | 1.781 | 1.753 |
| 1240 | | | 1.927 | 1.905 | 1.888 | 1.863 | 1.844 | 1.817 | 1.765 | 1.773 | 1.749 |
| 1250 | | | 1.921 | 1.899 | 1.882 | 1.857 | 1.838 | 1.811 | 1.760 | 1.766 | 1.744 |
| 1260 | | | 1.915 | 1.894 | 1.877 | 1.851 | 1.833 | 1.806 | 1.755 | 1.758 | 1.739 |
| 1270 | | | 1.909 | 1.888 | 1.871 | 1.846 | 1.827 | 1.801 | 1.750 | 1.751 | 1.734 |
| 1280 | 1.941 | 1.922 | 1.903 | 1.883 | 1.865 | 1.840 | 1.822 | 1.796 | 1.745 | 1.743 | 1.730 |
| 1290 | 1.935 | 1.914 | 1.897 | 1.877 | 1.860 | 1.835 | 1.816 | 1.790 | 1.740 | 1.736 | 1.725 |
| 1300 | 1.928 | 1.906 | 1.891 | 1.872 | 1.854 | 1.829 | 1.811 | 1.785 | 1.735 | 1.728 | 1.720 |
| 1310 | 1.922 | 1.898 | 1.885 | 1.867 | 1.849 | 1.823 | 1.805 | 1.780 | 1.730 | 1.721 | 1.716 |
| 1320 | 1.915 | 1.891 | 1.879 | 1.861 | 1.843 | 1.818 | 1.800 | 1.774 | 1.725 | 1.713 | 1.711 |

TABLE 148 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % NaF) | $a$ | $b \cdot 10^4$ | Stand. error of est. |
|---|---|---|---|
| 0 | 2.3289 | −4.6803 | 0.0001 |
| 10 | 2.3973 | −5.0961 | 0.0001 |
| 20 | 2.4248 | −5.1137 | 0.0002 |
| 30 | 2.4709 | −5.2766 | 0.0001 |
| 40 | 2.5325 | −5.5523 | 0.0001 |
| 50 | 2.5565 | −5.5962 | 0.0001 |
| 60 | 2.5791 | −5.5747 | 0.0001 |
| 70 | 2.5784 | −5.4338 | 0.0001 |
| 80 | 2.6766 | −6.0429 | 0.0028 |
| 90 | 2.9187 | −7.7887 | 0.0001 |
| 100 | 2.7590 | −6.3915 | 0.0001 |

Reference: [75]. Data reported in numerical form.

TABLE 149. LiF-NaF: Viscosity

Numerical values (cp)

| $T$ | 40 Mol % NaF |
|---|---|
| 973.2 | 3.2 |
| 1073.2 | 2.35 |

Reference: [35]. Due to limited data the experimental values are given.

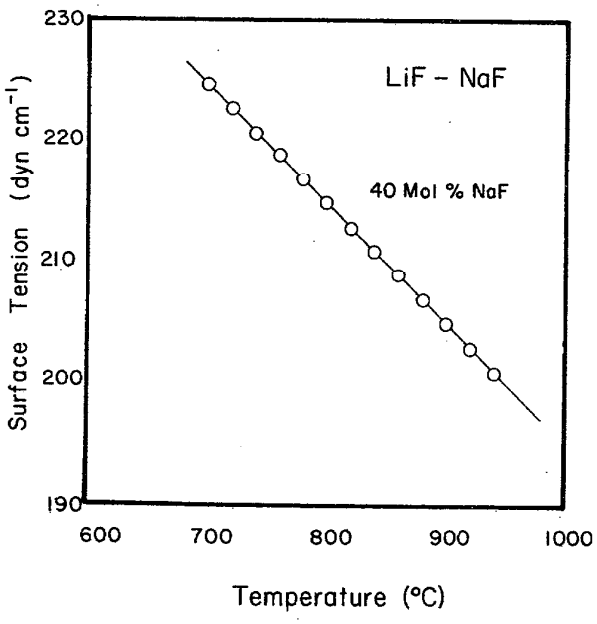


FIGURE 38. Plot [89] of surface tension against temperature for the system LiF-NaF.

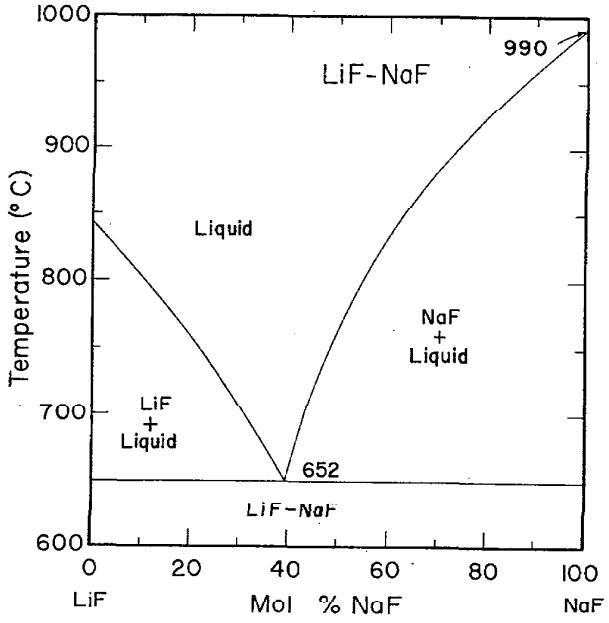


FIGURE 39. Temperature-composition phase diagram for LiF-NaF. A. G. Bergman and E. P. Dergunov, Compt. Rend. Acad. Sci., U.S.S.R., 31, 755 (1941).

## LiF-RbF

### Density

The recommended values in table 152 are based on the work of Cohen and Jones (Archimedean method) [35].

TABLE 150 A. Investigations critically re-examined

| Ref. | RbF (mol %) | Temp. range (T) |
|---|---|---|
| 35 | 57 | |

Comment: Cohen and Jones [35] report an experimental error of ±5 percent in their density measurements.

### Viscosity

The recommended values in table 153 are based on the work of Cohen and Jones (capillary and rotational pendulum methods) [35].

TABLE 151 A. Investigations critically re-examined

| Ref. | RbF (mol %) | Temp. range (T) |
|---|---|---|
| 35 | 57 | 773–923 |

Comment: Error limits for viscosity measurements in reference [35] were reported to be ±10 percent.

TABLE 152. LiF-RbF: Density

Temperature-dependent equation

$\rho = a + bT$ (gcm$^{-3}$)

| Comp. (mol % RbF) | $a$ | $b \cdot 10^4$ |
|---|---|---|
| 57 | 3.56 | −9.6 |

Reference: [35]. Data reported in equation form. No temperature range is given.

TABLE 153. LiF-RbF: Viscosity

*Numerical values (cp)*

| $T$ | 57 Mol % RbF |
|---|---|
| 773.2 | 9.0 |
| 823.2 | 6.2 |
| 873.2 | 4.5 |
| 923.2 | 3.4 |

Reference: [35]. Due to limited data the experimental values are given.

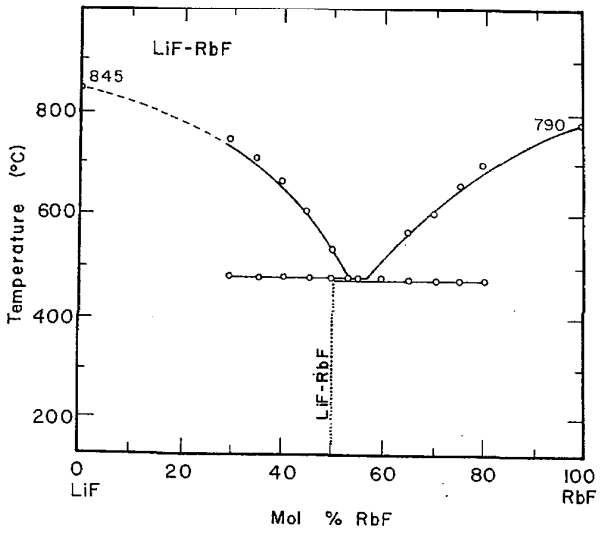


FIGURE 40. Temperature-composition phase diagram for LiF-RbF. E. P. Dergunov, Dokl. Akad. Nauk S.S.S.R., 58, 1369 (1947).

## LiF-$SmF_3$

### Electrical Conductance

The recommended values in table 156 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [87].

TABLE 154 A. Investigations critically re-examined

| Ref. | $SmF_3$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0, 10, 20, 30, 40, 50 | 1073–1343 |

TABLE 154 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $SmF_3$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 87 | 1 | 2 | 0 | 5.1 | (1150) | 8.2 | (1310) |

TABLE 154 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

Comment: The specific conductance values measured in reference [87] were reported reproducible to ±1 percent. The precision of the measurements was ±3 percent. The measured resistance was found to be independent of frequency over the range 20 to 20,000 hertz.

## Density

The recommended values in tables 157, 158 are based on the work of Meaker, Porter, and Kesterke (Archimedean method) [87].

TABLE 155 A. Investigations critically re-examined

| Ref. | $SmF_3$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0–50 | 1073–1343 |

TABLE 155 B. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [87] | Molten KCl [87] |

## Melt Preparation and Purification

Reagent-grade chemicals were used in reference [87] and [98]. After vacuum drying at 400 °C the salts were cooled and combined in the correct proportions. The salts were then placed in graphite crucibles and heated under vacuum (50 microns) to 600 °C. For density and conductance measurements the mixtures were melted in an atmosphere of helium in a controlled-atmosphere chamber. Melt compositions were confirmed by analysis after density measurements.

TABLE 156 a. $LiF$-$SmF_3$: Electrical conductance

Specific conductance: Numerical values ($ohm^{-1}$ $cm^{-1}$)

Mol percent $SmF_3$

| $T$ | 50.0 | 40.0 | 30.0 | 20.0 | 10.0 | 0.0 |
|---|---|---|---|---|---|---|
| 1080 | | | 3.90 | | | |
| 1090 | | | 3.97 | | | |
| 1100 | | | 4.04 | 5.07 | | |
| 1110 | | | 4.10 | 5.14 | | |
| 1120 | | | 4.17 | 5.21 | 6.80 | |
| 1130 | | | 4.24 | 5.28 | 6.86 | |
| 1140 | | | 4.30 | 5.35 | 6.92 | |
| 1150 | | 3.70 | 4.37 | 5.42 | 6.99 | 9.10 |
| 1160 | | 3.76 | 4.44 | 5.50 | 7.05 | 9.16 |
| 1170 | | 3.82 | 4.50 | 5.57 | 7.11 | 9.22 |
| 1180 | | 3.89 | 4.57 | 5.64 | 7.18 | 9.27 |
| 1190 | | 3.95 | 4.63 | 5.71 | 7.24 | 9.33 |
| 1200 | | 4.01 | 4.70 | 5.78 | 7.30 | 9.39 |
| 1210 | | 4.07 | 4.77 | 5.85 | 7.37 | 9.45 |
| 1220 | | 4.13 | 4.83 | 5.92 | 7.43 | 9.51 |
| 1230 | | 4.19 | 4.90 | 5.99 | 7.49 | 9.57 |
| 1240 | | 4.25 | 4.97 | 6.06 | 7.55 | 9.62 |
| 1250 | | 4.31 | 5.03 | 6.13 | 7.62 | 9.68 |
| 1260 | 3.83 | 4.37 | 5.10 | 6.20 | 7.68 | 9.74 |
| 1270 | 3.87 | 4.43 | 5.16 | 6.27 | 7.74 | 9.80 |
| 1280 | 3.92 | 4.49 | 5.23 | 6.35 | 7.81 | 9.86 |
| 1290 | 3.96 | 4.55 | 5.30 | 6.42 | 7.87 | 9.92 |
| 1300 | 4.00 | 4.61 | 5.36 | 6.49 | 7.93 | 9.97 |
| 1310 | 4.05 | 4.67 | 5.43 | 6.56 | 7.99 | 10.03 |
| 1320 | 4.09 | 4.73 | 5.50 | 6.63 | 8.06 | 10.09 |
| 1330 | 4.14 | 4.79 | 5.56 | 6.70 | 8.12 | 10.15 |
| 1340 | 4.18 | 4.85 | 5.63 | 6.77 | 8.18 | 10.21 |

TABLE 156 b. Temperature-dependent equations

$\kappa = a + bT$ ($ohm^{-1}$ $cm^{-1}$)

| Comp. (mol % $SmF_3$) | $a$ | $b \cdot 10^3$ | Stand. deviation [87] |
|---|---|---|---|
| 0.0 | 2.395 | 5.830 | 0.0500 |
| 10.0 | −0.255 | 6.297 | 0.0477 |
| 20.0 | −2.721 | 7.083 | 0.0377 |
| 30.0 | −3.262 | 6.635 | 0.0371 |
| 40.0 | −3.265 | 6.059 | 0.0455 |
| 50.0 | −1.710 | 4.395 | 0.0311 |

Reference: [87]. Data reported in equation form.

TABLE 157 a. $LiF\text{-}SmF_3$: Density

Numerical values ($gcm^{-3}$)

Mol percent $SmF_3$

| $T$ | 50 | 45 | 40 | 35 | 30 | 25 | 20 | 15 | 10 | 5 | 0 | 35 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1080 | | | | | | 3.546 | 3.268 | 2.952 | | | | |
| 1095 | | | | | 3.781 | 3.533 | 3.255 | 2.941 | | | | |
| 1110 | | | | | 3.767 | 3.520 | 3.243 | 2.930 | 2.573 | | | |
| 1125 | | | | 3.977 | 3.753 | 3.507 | 3.231 | 2.919 | 2.564 | 2.159 | 1.697 | 3.977 |
| 1140 | | | | 3.963 | 3.740 | 3.494 | 3.219 | 2.908 | 2.554 | 2.151 | 1.691 | 3.963 |
| 1155 | | | | 3.949 | 3.726 | 3.481 | 3.207 | 2.898 | 2.545 | 2.144 | 1.686 | 3.949 |
| 1170 | | | | 3.935 | 3.713 | 3.469 | 3.196 | 2.887 | 2.536 | 2.136 | 1.680 | 3.935 |
| 1185 | | | 4.129 | 3.922 | 3.700 | 3.457 | 3.185 | 2.877 | 2.528 | 2.130 | 1.675 | 3.922 |
| 1200 | | | 4.115 | 3.909 | 3.688 | 3.445 | 3.174 | 2.868 | 2.520 | 2.123 | 1.671 | 3.909 |
| 1215 | | 4.300 | 4.102 | 3.896 | 3.675 | 3.433 | 3.163 | 2.858 | 2.512 | 2.117 | 1.666 | 3.896 |
| 1230 | | 4.287 | 4.089 | 3.883 | 3.663 | 3.422 | 3.153 | 2.849 | 2.504 | 2.111 | 1.662 | 3.883 |
| 1245 | | 4.274 | 4.075 | 3.870 | 3.651 | 3.410 | 3.142 | 2.840 | 2.496 | 2.105 | 1.658 | 3.870 |
| 1260 | 4.458 | 4.261 | 4.062 | 3.857 | 3.639 | 3.399 | 3.132 | 2.831 | 2.489 | 2.099 | 1.655 | 3.857 |
| 1275 | 4.446 | 4.248 | 4.050 | 3.845 | 3.627 | 3.388 | 3.123 | 2.823 | 2.482 | 2.094 | 1.652 | 3.845 |
| 1290 | 4.433 | 4.235 | 4.037 | 3.833 | 3.615 | 3.378 | 3.113 | 2.814 | 2.475 | 2.089 | 1.649 | 3.833 |
| 1305 | 4.420 | 4.222 | 4.025 | 3.821 | 3.604 | 3.367 | 3.104 | 2.806 | 2.469 | 2.084 | 1.646 | 3.821 |
| 1320 | 4.408 | 4.210 | 4.012 | 3.809 | 3.593 | 3.357 | 3.094 | 2.799 | 2.463 | 2.080 | 1.643 | 3.809 |
| 1335 | 4.395 | 4.197 | 4.000 | 3.797 | 3.582 | 3.347 | 3.085 | 2.791 | 2.457 | 2.076 | 1.641 | 3.797 |

TABLE 157 b. Two-dimensional equation and statistical parameters

$\rho = a + bC + cC^2 + dC^3 + eTC + fTC^2 + gCT^2$ ($gcm^{-3}$)

| $a$ | $b \cdot 10^2$ | $c \cdot 10^3$ | $d \cdot 10^6$ | $e \cdot 10^5$ | $f \cdot 10^7$ | $g \cdot 10^9$ | Max. percent departure | Stand. error of est. |
|---|---|---|---|---|---|---|---|---|
| 7.92402 | −7.07474 | 1.11561 | −9.07294 | −4.79804 | 2.99784 | 6.23976 | 0.69 (1073.2 K, 80 mol % LiF) | 0.006 |

Reference: [87] and [98] (for LiF). Data reported in equation form.
$C$ = mol percent LiF.

TABLE 158 a. LiF–$SmF_3$: Density

Numerical values ($gcm^{-3}$)

Mol percent $SmF_3$

| $T$ | 50.0 | 40.0 | 30.0 | 20.0 | 10.0 | 0.0 |
|---|---|---|---|---|---|---|
| 1080 | | | 3.811 | 3.247 | | |
| 1090 | | | 3.802 | 3.240 | | |
| 1100 | | | 3.792 | 3.234 | 2.570 | |
| 1110 | | | 3.783 | 3.227 | 2.565 | |
| 1120 | | | 3.774 | 3.221 | 2.561 | |
| 1130 | | | 3.765 | 3.214 | 2.556 | 1.699 |
| 1140 | | | 3.756 | 3.208 | 2.551 | 1.695 |
| 1150 | | | 3.746 | 3.201 | 2.547 | 1.692 |
| 1160 | | | 3.737 | 3.195 | 2.542 | 1.689 |
| 1170 | | | 3.728 | 3.188 | 2.537 | 1.685 |
| 1180 | | 4.117 | 3.719 | 3.182 | 2.533 | 1.682 |
| 1190 | | 4.110 | 3.710 | 3.175 | 2.528 | 1.679 |
| 1200 | | 4.102 | 3.700 | 3.169 | 2.523 | 1.675 |
| 1210 | | 4.095 | 3.691 | 3.162 | 2.518 | 1.672 |
| 1220 | | 4.088 | 3.682 | 3.156 | 2.514 | 1.669 |
| 1230 | | 4.080 | 3.673 | 3.149 | 2.509 | 1.666 |
| 1240 | | 4.073 | 3.664 | 3.143 | 2.504 | 1.662 |
| 1250 | 4.467 | 4.065 | 3.655 | 3.137 | 2.500 | 1.659 |
| 1260 | 4.459 | 4.058 | 3.645 | 3.130 | 2.495 | 1.656 |
| 1270 | 4.451 | 4.051 | 3.636 | 3.124 | 2.490 | 1.652 |
| 1280 | 4.442 | 4.043 | 3.627 | 3.117 | 2.486 | 1.649 |
| 1290 | 4.434 | 4.036 | 3.618 | 3.111 | 2.481 | 1.646 |
| 1300 | 4.426 | 4.029 | 3.609 | 3.104 | 2.476 | 1.642 |
| 1310 | 4.417 | 4.021 | 3.599 | 3.098 | 2.471 | 1.639 |
| 1320 | 4.409 | 4.014 | 3.590 | 3.091 | 2.467 | 1.636 |
| 1330 | 4.401 | 4.006 | 3.581 | 3.085 | 2.462 | 1.632 |
| 1340 | 4.392 | 3.999 | 3.572 | 3.078 | 2.457 | 1.629 |

TABLE 158 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % $SmF_3$) | $a$ | $b \cdot 10^4$ | Stand. deviation [87, 98] |
|---|---|---|---|
| 0.0 | 2.074 | −3.321 | 0.00705 |
| 10.0 | 3.087 | −4.702 | 0.0083 |
| 20.0 | 3.946 | −6.474 | 0.0144 |
| 30.0 | 4.803 | −9.187 | 0.0126 |
| 40.0 | 4.987 | −7.372 | 0.0153 |
| 50.0 | 5.512 | −8.357 | 0.0953 |

References: [87] and [98] (for LiF). Data reported in equation form.

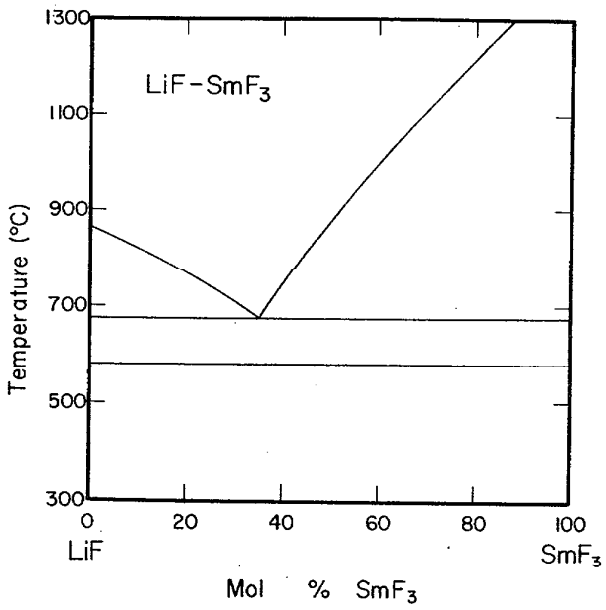


FIGURE 41. Temperature-composition phase diagram for LiF-$SmF_3$. R. E. Thoma, Progress in Science and Technology of the Rare Earths, Vol. 2, p. 110, Pergamon Press, N.Y. 1966.

## LiF-$ThF_4$

### Electrical Conductance

The recommended values in table 161 are based on the work of Brown and Porter (classical ac technique) [24].

TABLE 159 A. Investigations critically re-examined

| Ref. | $ThF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| **24** | 0–49.8 | 913–1273 |
| 100* | 3.2, 22, 49.8 | 913–1273 |
| 87 | 0–49.8 | 913–1343 |

* Data from reference [24].

TABLE 159 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $ThF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| **24** | 1 | 3 | 0 | 5.0 | (1160) | 6.8 | (1270) |
| 87 | 1 | 3 | 0 | 5.0 | (1160) | 6.8 | (1270) |

TABLE 159 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) | Calibration |
|---|---|---|---|
| Boron nitride cylinders with graphite jackets, melt contained in graphite crucible [24, 87]. | Mo tubes [24, 87] | 1000–20,000 experimental values at 10,000 [24]<br>20–20,000 experimental values at 10,000 [87] | Molten KCl [24] |

Comment: Measured resistances in reference [24] did not vary over the frequency range of 1,000 to to 20,000 hertz. Experimental conductivities were corrected for the resistance of the boron nitride cell. The specific conductance values were observed to be reproducible to ±1 percent.

Remarks concerning reference [87] are discussed under the $CaF_2$-LiF system. Electrical conductivity values reported by Porter, Meaker and Kesterke [87] are identical to the earlier values of Porter and Brown [24].

## Density

The recommended values in table 162 are based on the work of Hill, Cantor, and Ward (Archimedean method) [60].

TABLE 160 A. Investigations critically re-examined

| Ref. | $ThF_4$ (mol %) | Temp. range (T) |
|---|---|---|
| 24 | 0–49.8 | 928–1273 |
| **60** | 0–100 | 1024–1508 |
| 87 | 0–49.8 (graphical) | 1273 |
| 98 | 0–49.8 | 928–1353 |

TABLE 160 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $ThF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| 60 | 1 | 4 | 100 | 2.5 | (1390) | 2.8 | (1500) |
| 24 | 1 | 2 | 0 | 0.0 | (1180) | −1.1 | (1260) |
| **60** | 1 | 2 | 0 | 0.0 | (1180) | −0.6 | (1310) |
| 98 | 1 | 2 | 0 | −4.5 | (1310) | −5.6 | (1150) |
| 24 | 4.1 | 86 | 0 | 0.0 | (1180) | −1.1 | (1310) |
| 98 | 4.1 | 86 | 0 | −5.6 | (1123) | −4.4 | (1323) |

TABLE 160 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Biconical Mo plummet suspended from Mo wire, melt contained in graphite crucible [24, 87, 98]. | Molten KCl [24] |
| Pt plummet suspended by Pt-Rh wire, melt contained in a nickel cup [60] | Distilled water [60] |

Comment: Hill et al. [60] corrected for the surface tension effect of water upon the suspension wire and for the thermal expansion of the Pt plummet with temperature.

Brief remarks concerning references [24] and [98] are given under the system $NaF$-$ThF_4$. Density values in references [98] and [60] were given in the form of linear temperature-dependent equations. The range of standard deviation in $gcm^{-3}$ in reference [60] was $0.13\times10^{-4}$ (18.64 mol % $ThF_4$) to $12.0\times10^{-3}$ (80 mol % $ThF_4$); the range reported in reference [98] was $7.05\times10^{-3}$ (0 mol % $ThF_4$) to $30.0\times10^{-3}$ (22 mol % $ThF_4$).

## Melt Preparation and Purification

Brown and Porter [24] used commercial sources of LiF and $ThF_4$ which on analysis showed less than 0.01 percent metallic contaminants. The individual salts were combined in the desired proportions, vacuum dried to 400 °C at pressures less than 100 μm Hg, and then melted in an atmosphere of helium.

Hill et al. [60] purified LiF (Baker and Adamson Reagent Grade) by recrystallizing from slowly cooled melts, from which only clear crystal fragments were selected for use. Spectrochemical analysis showed three metallic impurities were present in concentration greater than 0.01 percent: Al, 0.05 percent; Ca, 0.015 percent; Ni, 0.075 percent. Thorium tetrafluoride was recrystallized in a graphite crucible by slowly heating the commercial, anhydrous product (National Lead Co.) to melting under a He atmosphere. Analysis showed only calcium (0.03%) to be present in large amounts.

The procedure used by Porter et al. [87, 98] is discussed under the system $CaF_2$-LiF.

TABLE 161 a. $LiF–ThF_4$: Electrical conductance*

Specific conductance: Numerical values ($ohm^{-1}$ $cm^{-1}$)

Mol percent $ThF_4$

| $T$ | 49.8 | 41.8 | 28.1 | 22.0 | 3.2 | 0 |
|---|---|---|---|---|---|---|
| 920 | | | 2.06 | 2.55 | | |
| 940 | | | 2.19 | 2.71 | | |
| 960 | | | 2.32 | 2.86 | | |
| 980 | | | 2.44 | 3.01 | | |
| 1000 | | | 2.57 | 3.16 | | |
| 1020 | | | 2.70 | 3.31 | | |
| 1040 | | | 2.82 | 3.46 | | |
| 1060 | | | 2.95 | 3.61 | | |
| 1080 | | 2.45 | 3.08 | 3.71 | | |
| 1100 | 2.16 | 2.55 | 3.21 | 3.92 | | |
| 1120 | 2.24 | 2.65 | 3.33 | 4.07 | | |
| 1140 | 2.33 | 2.74 | 3.46 | 4.22 | | |
| 1160 | 2.41 | 2.84 | 3.59 | 4.37 | 7.22 | 9.16 |
| 1180 | 2.49 | 2.94 | 3.71 | 4.52 | 7.43 | 9.28 |
| 1200 | 2.58 | 3.04 | 3.84 | 4.68 | 7.65 | 9.39 |
| 1220 | 2.66 | 3.14 | 3.97 | 4.83 | 7.87 | 9.51 |
| 1240 | 2.75 | 3.23 | 4.09 | 4.98 | 8.09 | 9.63 |
| 1260 | 2.83 | 3.33 | 4.22 | 5.13 | 8.31 | 9.75 |
| 1270 | 2.87 | 3.38 | 4.28 | 5.21 | 8.42 | 9.80 |

TABLE 161 b. Temperature-dependent equations

$\kappa = a + bT$ ($ohm^{-1}$ $cm^{-1}$)

| Comp. (mol % $ThF_4$) | $a$ | $b \cdot 10^3$ |
|---|---|---|
| 0 | 2.40 | 5.83 |
| 3.2 | −5.51 | 10.97 |
| 22.0 | −4.42 | 7.58 |
| 28.1 | −3.78 | 6.35 |
| 41.8 | −2.83 | 4.89 |
| 49.8 | −2.45 | 4.19 |

Reference: [24]. Data reported in equation form.

TABLE 162 a. $LiF–ThF_4$: Density

Numerical values ($gcm^{-3}$)

Mol percent $ThF_4$

| $T$ | 100 | 80.00 | 60.00 | 40.00 | 20.00 | 18.64 | 0 |
|---|---|---|---|---|---|---|---|
| 1020 | | | | | 3.926 | | |
| 1040 | | | | | 3.909 | 3.932 | |
| 1060 | | | | | 3.892 | 3.914 | |
| 1080 | | | | 5.035 | 3.875 | 3.895 | |
| 1100 | | | | 5.014 | 3.859 | 3.877 | |
| 1120 | | | | 4.993 | 3.842 | 3.859 | |
| 1140 | | | | 4.972 | 3.825 | 3.840 | 1.801 |
| 1160 | | | | 4.951 | 3.808 | 3.822 | 1.791 |
| 1180 | | | | 4.931 | 3.791 | 3.803 | 1.781 |
| 1200 | | | | 4.910 | 3.774 | 3.785 | 1.771 |
| 1220 | | | 5.567 | 4.889 | 3.757 | 3.767 | 1.761 |
| 1240 | | | 5.544 | 4.868 | | | 1.751 |
| 1260 | | | 5.522 | 4.847 | | | 1.741 |
| 1280 | | | 5.500 | | | | 1.731 |
| 1300 | | | 5.478 | | | | 1.721 |
| 1320 | | 5.981 | 5.455 | | | | 1.711 |
| 1340 | | 5.960 | 5.433 | | | | 1.701 |
| 1360 | | 5.940 | 5.411 | | | | 1.691 |
| 1380 | | 5.919 | | | | | |
| 1400 | 6.209 | 5.898 | | | | | |
| 1420 | 6.193 | 5.877 | | | | | |
| 1440 | 6.176 | 5.856 | | | | | |
| 1460 | 6.160 | | | | | | |
| 1480 | 6.144 | | | | | | |
| 1500 | 6.128 | | | | | | |

TABLE 162 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % $ThF_4$) | $a$ | $b \cdot 10^4$ |
|---|---|---|
| 0 | 2.371 | −5.00 |
| 18.64 | 4.889 | −9.20 |
| 20.00 | 5.787 | −8.44 |
| 40.00 | 6.159 | −10.41 |
| 60.00 | 6.927 | −11.15 |
| 80.00 | 7.354 | −10.40 |
| 100 | 7.340 | −8.08 |

Reference: [60]. Data reported in equation form. Two-dimensional statistical analysis was unsuccessful.

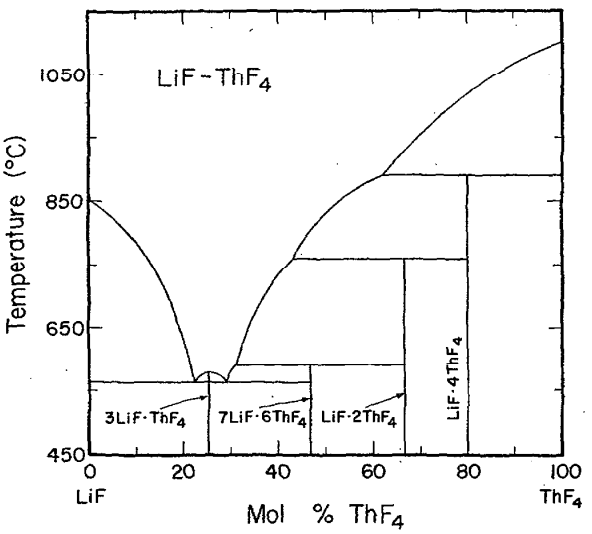


FIGURE 42. Temperature-composition phase diagram for LiF-$ThF_4$. R. E. Thoma, H. Insley, B. S. Landau, H. A. Friedman, and W. R. Grimes, J. Phys. Chem., **63**, 1127 (1959).

## LiF-$UF_4$

### Electrical Conductance

The recommended values in table 166 are based on the work of Brown and Porter (classical ac technique) [24].

TABLE 163 A. Investigations critically re-examined

| Ref. | $UF_4$ (mol %) | Temp. range (*T*) |
|---|---|---|
| **24** | 0–60 | 923–1273 |
| 100* | 5, 40, 60 | 973–1273 |
| 87 | 0–60 | 923–1343 |

* Data from reference [24].

TABLE 163 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $UF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (*T*) | % (max) | (*T*) |
| **24** | 1 | 2 | 0 | 5.0 | (1160) | 6.8 | (1270) |
| 87 | 1 | 2 | 0 | 5.0 | (1160) | 6.8 | (1270) |

TABLE 163 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) | Calibration |
|---|---|---|---|
| Boron nitride cylinders with graphite jackets, melt contained in graphite crucible [24, 87] | Mo tubes [24, 87] | 1000–20,000 experimental values at 10,000 [24]<br>20–20,000 experimental values at 10,000 [87] | Molten KCl [24] |

Comment: Remarks concerning references [24] and [87] are given under the systems LiF-$ThF_4$ and $CaF_2$-LiF, respectively. Electrical conductivity values reported by Porter, Meaker and Kesterke [87] are identical to the earlier values of Porter and Brown [24].

### Density

The recommended values in table 167 are based on the work of Porter and Meaker (Archimedean method) [78].

TABLE 164 A. Investigations critically re-examined

| Ref. | $UF_4$ (mol %) | Temp. range (*T*) |
|---|---|---|
| 24 | 0–60 | 973–1273 |
| 18 | 0–47 | 973, 1073 |
| 87 | 0–60 (graphical) | 1273 |
| **98** | 0–60 | 973–1353 |

TABLE 164 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $UF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (*T*) | % (max) | (*T*) |
| 24 | 1 | 2 | 0 | 0.0 | (1180) | −1.1 | (1260) |
| **98** | 1 | 2 | 0 | −4.5 | (1310) | −5.6 | (1150) |

TABLE 164 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Biconical Mo plummet suspended from Mo wire, melt contained in graphite crucible [24, 87, 98] | Molten KCl [24] |
| Pt cylinder and Pt suspension wire, melt contained in Inconel crucible [78] | |

Comment: Brief remarks concerning references [24] and [98] are given under the system NaF–$ThF_4$. Density values in [98] were in the form of linear temperature-dependent equations with standard deviations in the range: $7.05\times10^{-3}$ gcm$^{-3}$ (0 mol % $UF_4$) to $36.0\times10^{-3}$ gcm$^{-3}$ (27.5 mol % $UF_4$).

### Viscosity

The recommended values in table 168 are based on the work of Blanke et al. (rotational cylinder method) [18].

TABLE 165 A. Investigations critically re-examined

| Ref. | $UF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 18 | 0–47 | 873, 973, 1073 |

TABLE 165 B. Cell materials and calibration

| Cell material |
|---|
| Two concentric Inconel cylinders, nickel shaft connected to inner Mo torsion wire [18]. |

Comment: the overall error for viscosity measurements in reference [18] was ±5 percent.

### Melt Preparation and Purification

Brown and Porter [24] used commercial sources of LiF and $UF_4$ which on analysis showed less than 0.01 percent metallic contaminants. The individual salts were combined in the desired proportions, vacuum dried to 400 °C (pressure less than 100 μm Hg), and then melted in an atmosphere of helium.

The procedure used by Porter et al. [87, 98] is discussed under the system $CaF_2$-LiF.

TABLE 166 a. LiF-$UF_4$: Electrical conductance

Specific conductance: Numerical values (ohm$^{-1}$ cm$^{-1}$)

| | Mol percent $UF_4$ | | | | | | |
|---|---|---|---|---|---|---|---|
| $T$ | 60.0 | 50.0 | 40.0 | 27.5 | 15.0 | 5.0 | 0 |
| 940 | | | | 2.50 | | | |
| 960 | | | | 2.62 | | | |
| 980 | | | 2.21 | 2.74 | | | |
| 1000 | | | 2.32 | 2.86 | | | |
| 1020 | | | 2.43 | 2.98 | | | |
| 1040 | | | 2.55 | 3.10 | | | |
| 1060 | | | 2.66 | 3.22 | | | |
| 1080 | | 2.48 | 2.77 | 3.34 | 4.81 | | |
| 1100 | | 2.57 | 2.89 | 3.46 | 4.93 | | |
| 1120 | | 2.66 | 3.00 | 3.58 | 5.05 | | |
| 1140 | | 2.76 | 3.12 | 3.70 | 5.18 | | |
| 1160 | | 2.85 | 3.23 | 3.82 | 5.30 | | 9.16 |
| 1180 | 2.91 | 2.94 | 3.34 | 3.94 | 5.42 | 7.59 | 9.28 |
| 1200 | 2.98 | 3.03 | 3.46 | 4.06 | 5.55 | 7.71 | 9.39 |
| 1220 | 3.04 | 3.12 | 3.57 | 4.18 | 5.67 | 7.83 | 9.51 |
| 1240 | 3.11 | 3.22 | 3.68 | 4.30 | 5.80 | 7.95 | 9.63 |
| 1260 | 3.18 | 3.31 | 3.80 | 4.42 | 5.92 | 8.06 | 9.75 |
| 1270 | 3.21 | 3.35 | 3.85 | 4.48 | 5.98 | 8.12 | 9.80 |

TABLE 166 b. Temperature-dependent equations

$\kappa = a + bT$ (ohm$^{-1}$ cm$^{-1}$)

| Comp. (mol % $UF_4$) | $a$ | $b\cdot10^3$ |
|---|---|---|
| 0 | 2.40 | 5.83 |
| 5.0 | 0.68 | 5.86 |
| 15.0 | −1.88 | 6.19 |
| 27.5 | −3.13 | 5.99 |
| 40.0 | −3.36 | 5.60 |
| 50.0 | −2.50 | 4.61 |
| 60.0 | −0.97 | 3.29 |

Reference: [24]. Data reported in equation form.

TABLE 167 a. $LiF-UF_4$: Density

Numerical values ($gcm^{-3}$)

Mol percent $UF_4$

| $T$ | 60.0 | 50.0 | 40.0 | 27.5 | 15.0 | 0.0 |
|---|---|---|---|---|---|---|
| 980 | | | 5.242 | 4.858 | | |
| 1000 | | | 5.219 | 4.833 | | |
| 1020 | | | 5.196 | 4.808 | 3.718 | |
| 1040 | | 5.625 | 5.172 | 4.782 | 3.703 | |
| 1060 | | 5.599 | 5.149 | 4.757 | 3.689 | |
| 1080 | | 5.573 | 5.125 | 4.731 | 3.674 | |
| 1100 | 6.032 | 5.548 | 5.102 | 4.706 | 3.660 | |
| 1120 | 5.998 | 5.522 | 5.078 | 4.680 | 3.645 | |
| 1140 | 5.964 | 5.496 | 5.055 | 4.655 | 3.631 | 1.695 |
| 1160 | 5.931 | 5.471 | 5.031 | 4.629 | 3.616 | 1.689 |
| 1180 | 5.897 | 5.445 | 5.008 | 4.604 | 3.601 | 1.682 |
| 1200 | 5.863 | 5.419 | 4.984 | 4.579 | 3.587 | 1.675 |
| 1220 | 5.829 | 5.394 | 4.961 | 4.553 | 3.572 | 1.669 |
| 1240 | 5.795 | 5.368 | 4.937 | 4.528 | 3.558 | 1.662 |
| 1260 | 5.762 | 5.342 | 4.914 | 4.502 | 3.543 | 1.656 |
| 1280 | 5.728 | 5.317 | 4.890 | 4.477 | 3.529 | 1.649 |
| 1300 | 5.694 | 5.291 | 4.867 | 4.451 | 3.514 | 1.642 |
| 1320 | 5.660 | 5.265 | 4.843 | 4.426 | 3.499 | 1.636 |
| 1340 | 5.626 | 5.240 | 4.820 | 4.401 | 3.485 | 1.629 |

TABLE 167 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % $UF_4$) | $a$ | $b \cdot 10^4$ | Stand. deviation [98] |
|---|---|---|---|
| 0.0 | 2.074 | −3.321 | 0.00705 |
| 15.0 | 4.461 | −7.285 | 0.0216 |
| 27.5 | 6.105 | −12.720 | 0.0360 |
| 40.0 | 6.393 | −11.740 | 0.0200 |
| 50.0 | 6.959 | −12.830 | 0.0179 |
| 60.0 | 7.891 | −16.900 | 0.0347 |

Reference: [98]. Data reported in equation form.

TABLE 168. $LiF-UF_4$: Viscosity

Numerical values (cp)

Mol percent $UF_4$

| $T$ | 47 | 35 | 20 | 12 | 0* |
|---|---|---|---|---|---|
| 873.2 | | 25.6 | 16.2 | | |
| 973.2 | 16.1 | 15.3 | 8.81 | | |
| 1073.2 | 9.81 | 10.05 | 5.39 | 6.04 | 2.32 |

Reference: [18]. Due to limited data the experimental values are given.

* Extrapolated.

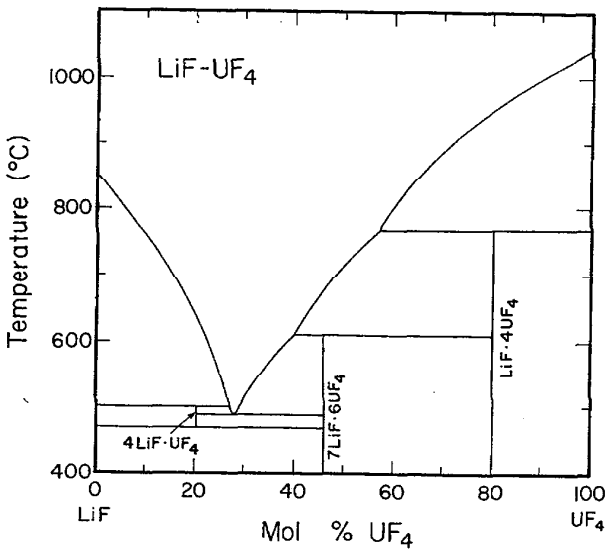


FIGURE 43. Temperature-composition phase diagram for $LiF-UF_4$. C. J. Barton, H. A. Friedman, W. R. Grimes, H. Insley, R. E. Moore, and R. E. Thoma, J. Amer. Ceram. Soc., **41**[2], 67 (1958).

## $LiF-YF_3$

### Electrical Conductance

The recommended values in table 171 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [**87**].

TABLE 169 A. Investigations critically re-examined

| Ref. | $YF_3$ (mol %) | Temp. range ($T$) |
|---|---|---|
| **87** | 0, 19, 30, 40, 50, 60 | 973–1343 |

TABLE 169 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $YF_3$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| **87** | 1 | 2 | 100 | 5.1 | (1150) | 8.2 | (1310) |

TABLE 169 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

Comment: The specific conductance values measured in reference [87] were reported reproducible to ±1 percent. The precision of the measurements was ±3 percent. The measured resistance was found to be independent of frequency over the range 20 to 20,000 hertz.

## Density

The recommended values in table 172 are based on the work of Porter and Meaker (Archimedean method) [98].

TABLE 170 A. Investigations critically re-examined

| Ref. | $YF_3$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0, 19, 30, 40, 50, 60 (graphical) | 1273 |
| 98 | 0, 19, 30, 40, 50, 60 | 973–1353 |

TABLE 170 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $YF_3$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 98 | 1 | 2 | 100 | −4.5 | (1310) | −5.6 | (1150) |

TABLE 170 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [87, 98] | Molten KCl [87, 98] |

Comment: Brief remarks concerning reference [98] are given under the system $CaF_2$–LiF.

Density values [98] were fitted to linear temperature-dependent equations with standard deviations in the range: $7.05\times10^{-3}$ (100 mol % LiF) to $23.1\times10^{-3}$ gcm$^{-3}$ (60 mol % $YF_3$).

## Melt Preparation and Purification

The method used by Porter et al. [87, 98] is described under the system $CaF_2$-LiF. Yttrium fluoride contained less than 0.1 weight-percent of metallic impurities.

TABLE 171 a. LiF-$YF_3$: Electrical conductance

Specific conductance: Numerical values (ohm$^{-1}$ cm$^{-1}$)

| $T$ | Mol percent $YF_3$ | | | | | |
|---|---|---|---|---|---|---|
| | 60.0 | 50.0 | 40.0 | 30.0 | 19.0 | 0.0 |
| 980 | | | | | 4.10 | |
| 1000 | | | | | 4.25 | |
| 1020 | | | | | 4.39 | |
| 1040 | | | | | 4.54 | |
| 1060 | | | | | 4.69 | |
| 1080 | | | 2.82 | 3.73 | 4.84 | |
| 1100 | | | 2.96 | 3.85 | 4.98 | |
| 1120 | | | 3.10 | 3.98 | 5.13 | |
| 1140 | | 2.51 | 3.23 | 4.10 | 5.28 | |
| 1160 | | 2.63 | 3.37 | 4.23 | 5.42 | 9.16 |
| 1180 | 2.48 | 2.75 | 3.51 | 4.36 | 5.57 | 9.27 |
| 1200 | 2.59 | 2.87 | 3.65 | 4.48 | 5.72 | 9.39 |
| 1220 | 2.70 | 2.99 | 3.79 | 4.61 | 5.87 | 9.51 |
| 1240 | 2.81 | 3.11 | 3.92 | 4.74 | 6.01 | 9.62 |
| 1260 | 2.92 | 3.24 | 4.06 | 4.86 | 6.16 | 9.74 |
| 1280 | 3.04 | 3.36 | 4.20 | 4.99 | 6.31 | 9.86 |
| 1300 | 3.15 | 3.48 | 4.34 | 5.11 | 6.46 | 9.97 |
| 1320 | 3.26 | 3.60 | 4.47 | 5.24 | 6.60 | 10.09 |
| 1340 | 3.37 | 3.72 | 4.61 | 5.37 | 6.75 | 10.21 |

TABLE 171 b. Temperature-dependent equations

$\kappa = a + bT$ (ohm$^{-1}$ cm$^{-1}$)

| Comp. (mol % $YF_3$) | $a$ | $b\cdot10^3$ | Stand. deviation [87] |
|---|---|---|---|
| 0.0 | 2.395 | 5.830 | 0.0500 |
| 19.0 | −3.117 | 7.363 | 0.0529 |
| 30.0 | −3.088 | 6.309 | 0.0309 |
| 40.0 | −4.634 | 6.901 | 0.0278 |
| 50.0 | −4.415 | 6.072 | 0.0205 |
| 60.0 | −4.146 | 5.611 | 0.0123 |

Reference: [87]. Data reported in equation form.

TABLE 172 a. LiF-$YF_3$: Density

Numerical values ($gcm^{-3}$)

Mol percent $YF_3$

| T | 60.0 | 50.0 | 40.0 | 30.0 | 19.0 | 0.0 |
|---|---|---|---|---|---|---|
| 980 | | | | | 2.706 | |
| 1000 | | | | | 2.694 | |
| 1020 | | | | | 2.683 | |
| 1040 | | | | | 2.672 | |
| 1060 | | | | | 2.661 | |
| 1080 | | | 3.237 | 2.974 | 2.650 | |
| 1100 | | | 3.225 | 2.961 | 2.639 | |
| 1120 | | 3.479 | 3.213 | 2.948 | 2.627 | |
| 1140 | | 3.464 | 3.200 | 2.934 | 2.616 | 1.695 |
| 1160 | | 3.450 | 3.188 | 2.921 | 2.605 | 1.689 |
| 1180 | | 3.436 | 3.176 | 2.908 | 2.594 | 1.682 |
| 1200 | | 3.421 | 3.164 | 2.894 | 2.583 | 1.675 |
| 1220 | 3.556 | 3.407 | 3.151 | 2.881 | 2.571 | 1.669 |
| 1240 | 3.546 | 3.392 | 2.139 | 2.868 | 2.560 | 1.662 |
| 1260 | 3.536 | 3.378 | 3.127 | 2.854 | 2.549 | 1.656 |
| 1280 | 3.526 | 3.363 | 3.114 | 2.841 | 2.538 | 1.649 |
| 1300 | 3.516 | 3.349 | 3.102 | 2.828 | 2.527 | 1.642 |
| 1320 | 3.505 | 3.334 | 3.090 | 2.814 | 2.515 | 1.636 |
| 1340 | 3.495 | 3.320 | 3.077 | 2.801 | 2.504 | 1.629 |

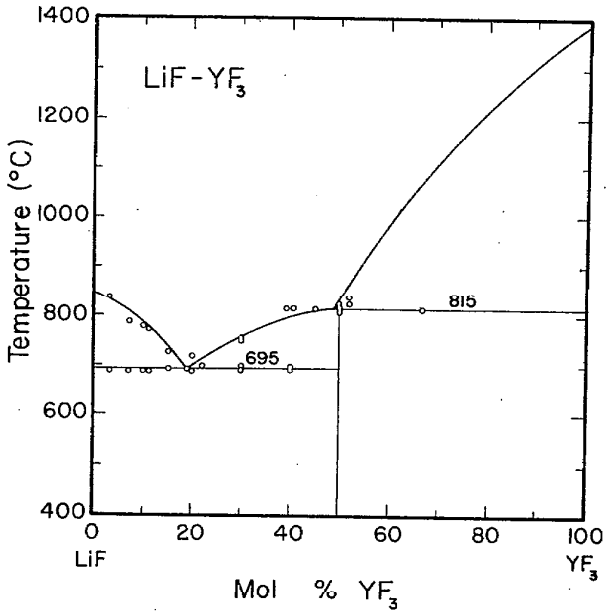


FIGURE 44. Temperature-composition phase diagram for LiF-$YF_3$. R. E. Thoma, C. F. Weaver, and H. A. Friedman, unpublished work performed at Oakridge National Laboratory 1958–59.

TABLE 172 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % $YF_3$) | a | $b \cdot 10^4$ | Stand. dev. [98] |
|---|---|---|---|
| 0.0 | 2.074 | −3.321 | 0.000705 |
| 19.0 | 3.254 | −5.595 | 0.0130 |
| 30.0 | 3.695 | −6.672 | 0.0213 |
| 40.0 | 3.902 | −6.154 | 0.014 |
| 50.0 | 4.287 | −7.216 | 0.0117 |
| 60.0 | 4.174 | −5.065 | 0.0231 |

Reference: [98]. Data reported in equation form.

## $NaF-NaBF_4$

### Electrical Conductance

The recommended values in table 177 are based on the work of Selivanov and Stender (classical ac technique) **[125]**.

TABLE 173 A. Investigations critically re-examined

| Ref. | $NaBF_4$ (mol %) | Temp. range (T) |
|---|---|---|
| **125** | 20.3–77.5 | 723–1073 |
| 124* | 92, 100 | 773 |

* Data taken from reference **[125]**.

TABLE 173 B. Cell materials and calibration.

| Cell Material | Electrodes | Frequency range (Hz) | Calibration |
|---|---|---|---|
| Corundum crucible [125] | Pt [125] | 5000 [125] | Melt containing 62% CaCl −38% NaCl and molten $Na_2B_4O_7$ [125] |

Comment: Cantor [124] combined calculated data for $NaBF_4$ with the results given in reference [125] to interpolate conductance values for the 92 mol percent $NaBF_4$ composition.

## Density

The recommended values in table 178 are based on the work of Cantor (dilatometric method) [123].

TABLE 174 A. Investigations critically re-examined

| Ref. | $NaBF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 122* | 92 | 727, 894 |
| 123 | 92 | 673–864 |

* Data in reference [122] are estimates.

## Viscosity

The recommended values in table 179 are based on the work of Cantor (oscillating hollow cylinder method) [123].

TABLE 175 A. Investigations critically re-examined

| Ref. | $NaBF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 122* | 92 | 727, 894 |
| 123 | 92, 100 | 681–810 |

*Data in reference [122] are estimates.

## Surface Tension

The recommended values in table 180 are based on the work of Cantor et al. [124].

TABLE 176 A. Investigations critically re-examined

| Ref. | $NaBF_4$ (mol %) |
|---|---|
| 124* | 92, 100 |

* The data reported in reference [124] are estimates.

TABLE 177. NaF-$NaBF_4$: Electrical conductance

Specific conductance: Numerical values ($ohm^{-1}$ $cm^{-1}$)

Mol percent $NaBF_4$

| $T$ | 77.5 | 60.5 | 47.2 | 36.5 | 27.7 | 20.3 |
|---|---|---|---|---|---|---|
| 723.2 | 2.408 | 2.019 | 1.559 | 0.905 | | |
| 773.2 | 4.093 | 3.408 | 2.755 | 1.601 | | |
| 823.2 | 5.445 | 4.810 | 4.115 | 2.501 | | |
| 873.2 | 6.955 | 6.600 | 6.015 | 4.755 | 2.955 | |
| 923.2 | 8.801 | 8.555 | 7.950 | 6.350 | 4.095 | |
| 973.2 | 10.305 | 10.425 | 10.101 | 7.803 | 5.015 | |
| 1023.2 | 11.955 | 12.300 | 12.375 | 10.997 | 7.451 | 4.108 |
| 1073.2 | 14.978 | 15.375 | 15.201 | 14.105 | 12.075 | 6.502 |

Reference: [125]. The statistical analysis was unsuccessful therefore the original data are reported.

TABLE 178 a. NaF-$NaBF_4$: Density

Numerical values ($gcm^{-3}$)

| $T$ | 92 Mol % $NaBF_4$ |
|---|---|
| 680 | 1.963 |
| 700 | 1.948 |
| 720 | 1.934 |
| 740 | 1.920 |
| 760 | 1.906 |
| 780 | 1.891 |
| 800 | 1.877 |
| 820 | 1.863 |
| 840 | 1.849 |
| 860 | 1.835 |

TABLE 178 b. Temperature-dependent equation

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % $NaBF_4$) | $a$ | $b \cdot 10^4$ | Stand. error [123] |
|---|---|---|---|
| 92 | 2.446 | 7.11 | 0.0018 |

Reference: [123]. Data reported in equation form.

TABLE 179 a. $NaF\text{-}NaBF_4$: Viscosity

Numerical values (cp)

Mol percent $NaBF_4$

| $T$ | 100 | 92 |
|---|---|---|
| 690 | | 2.25 |
| 700 | 2.42 | 2.15 |
| 710 | 2.31 | 2.06 |
| 720 | 2.21 | 1.97 |
| 730 | 2.11 | 1.89 |
| 740 | 2.02 | 1.81 |
| 750 | 1.93 | 1.74 |
| 760 | 1.86 | 1.67 |
| 770 | 1.78 | 1.61 |
| 780 | 1.71 | 1.55 |
| 790 | | 1.49 |
| 800 | | 1.44 |
| 810 | | 1.39 |

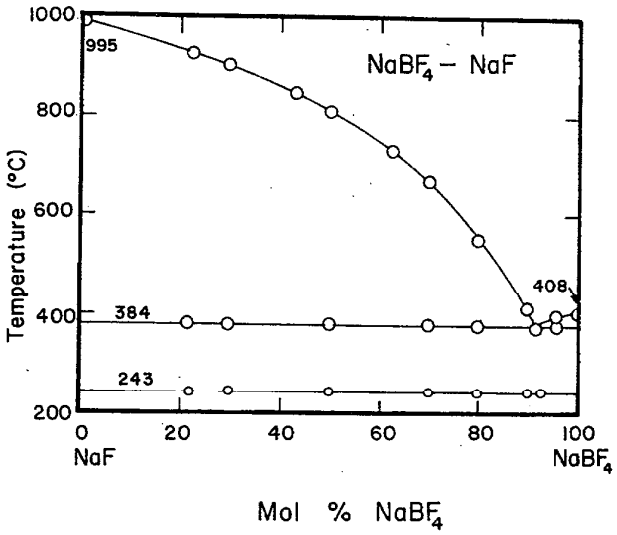


FIGURE 45. Temperature-composition phase diagram for $NaBF_4$-NaF.
M. W. Rosenthal, P. N. Haubenreich, and R. B. Briggs, Oak Ridge National Laboratory, ORNL-4812 (1972).

TABLE 179 b. Temperature-dependent equations

$\eta = A \cdot \exp(E/RT)$ (cp)

| Comp (mol % $NaBF_4$) | $A \cdot 10^2$ | $E$ (cal $mol^{-1}$) |
|---|---|---|
| 92 | 8.77 | 4451 |
| 100 | 8.32 | 4689 |

Reference: [123]. Data reported in equation form.

TABLE 180. $NaF\text{-}NaBF_4$: Surface tension

Temperature-dependent equation

$\gamma = a + bT$ (dyn $cm^{-1}$)

| Comp. (mol % $NaBF_4$) | $a$ | $b \cdot 10^{-2}$ | Uncertainty |
|---|---|---|---|
| 92 | 150 | 7.5 | ±30% |
| 100 | 140 | 7.5 | ±25% |

Reference: [124]. Data reported in equation form, no temperature ranges were given.

## $NaF\text{-}SmF_3$

### Electrical Conductance

The recommended values in table 183 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [87].

TABLE 181 A. Investigations critically re-examined

| Ref. | $SmF_3$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0, 10, 20, 30, 40, 50 | 1103–1343 |

TABLE 181 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $SmF_3$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 87 | 1 | 3 | 0 | 5.0 | (1300) | 7.4 | (1340) |

TABLE 181 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

Comment: The specific conductance values measured in reference [87] were reported reproducible to ±1 percent. The precision of the measurements was ±3 percent. The measured resistance was found to be independent of frequency over the range 20 to 20,000 hertz.

## Density

The recommended values in table 184 are based on the work of Meaker, Porter, and Kesterke (Archimedean method) [87].

TABLE 182 A. Investigations critically re-examined

| Ref. | $SmF_3$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0–50 | 1103–1343 |

TABLE 182 B. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [87] | Molten KCl [87] |

## Melt Preparation and Purification

Reagent-grade chemicals were used in references [87] and [98]. After vacuum drying at 400 °C the salts were cooled and combined in the correct proportions. The salts were then placed in graphite crucibles and heated under vacuum (50 μm Hg) to 600 °C. For density and conductance measurements the mixtures were melted in an atmosphere of helium in a controlled-atmosphere chamber. Melt compositions were confirmed by analyses after density measurements.

TABLE 183 a. NaF-$SmF_3$: Electrical conductance

Specific conductance: Numerical values ($ohm^{-1}cm^{-1}$)

Mol percent $SmF_3$

| $T$ | 50.0 | 40.0 | 30.0 | 20.0 | 10.0 | 0.0 |
|---|---|---|---|---|---|---|
| 1110 | | | | 2.88 | | |
| 1120 | | | 2.39 | 2.92 | | |
| 1130 | | | 2.43 | 2.97 | | |
| 1140 | | | 2.48 | 3.02 | | |
| 1150 | | 2.21 | 2.53 | 3.06 | | |
| 1160 | | 2.26 | 2.57 | 3.11 | | |
| 1170 | | 2.31 | 2.62 | 3.16 | | |
| 1180 | | 2.36 | 2.66 | 3.20 | 3.96 | |
| 1190 | | 2.41 | 2.71 | 3.25 | 4.01 | |
| 1200 | | 2.46 | 2.76 | 3.30 | 4.06 | |
| 1210 | | 2.51 | 2.80 | 3.34 | 4.11 | |
| 1220 | | 2.56 | 2.85 | 3.39 | 4.16 | |
| 1230 | | 2.61 | 2.89 | 3.43 | 4.21 | |
| 1240 | | 2.65 | 2.94 | 3.48 | 4.26 | |
| 1250 | | 2.70 | 2.99 | 3.53 | 4.31 | |
| 1260 | | 2.75 | 3.03 | 3.57 | 4.36 | |
| 1270 | | 2.80 | 3.08 | 3.62 | 4.41 | |
| 1280 | 2.65 | 2.85 | 3.01 | 3.67 | 4.46 | |
| 1290 | 2.70 | 2.90 | 3.17 | 3.71 | 4.51 | |
| 1300 | 2.74 | 2.95 | 3.22 | 3.76 | 4.56 | |
| 1310 | 2.79 | 3.00 | 3.26 | 3.81 | 4.60 | 5.33 |
| 1320 | 2.83 | 3.05 | 3.31 | 3.85 | 4.65 | 5.39 |
| 1330 | 2.87 | 3.10 | 3.35 | 3.90 | 4.70 | 5.44 |
| 1340 | 2.92 | 3.15 | 3.40 | 3.95 | 4.75 | 5.50 |

TABLE 183 b. Temperature-dependent equations

$\kappa = a + bT$ ($ohm^{-1}$ $cm^{-1}$)

| Comp. (mol % $SmF_3$) | $a$ | $b \cdot 10_3$ | Stand. deviation [87] |
|---|---|---|---|
| 0.0 | −2.060 | 5.640 | 0.0660 |
| 10.0 | −1.854 | 4.930 | 0.0260 |
| 20.0 | −2.301 | 4.663 | 0.0188 |
| 30.0 | −2.777 | 4.610 | 0.0176 |
| 40.0 | −3.458 | 4.929 | 0.0192 |
| 50.0 | −2.996 | 4.413 | 0.00843 |

Reference: [87]. Data reported in equation form.

TABLE 184 a. $NaF$-$SmF_3$: Density

Numerical values ($gcm^{-3}$)

Mol percent $SmF_3$

| $T$ | 50.0 | 40.0 | 30.0 | 20.0 | 10.0 | 0.0 |
|---|---|---|---|---|---|---|
| 1110 | | | 3.564 | 3.181 | | |
| 1120 | | | 3.557 | 3.173 | | |
| 1130 | | 3.968 | 3.550 | 3.165 | | |
| 1140 | | 3.960 | 3.543 | 3.157 | | |
| 1150 | | 3.952 | 3.536 | 3.148 | | |
| 1160 | | 3.943 | 3.530 | 3.140 | | |
| 1170 | | 3.935 | 3.523 | 3.132 | | |
| 1180 | | 3.927 | 3.516 | 3.123 | | |
| 1190 | | 3.919 | 3.509 | 3.115 | | |
| 1200 | | 3.910 | 3.502 | 3.107 | | |
| 1210 | | 3.902 | 3.495 | 3.099 | 2.535 | |
| 1220 | | 3.894 | 3.488 | 3.090 | 2.529 | |
| 1230 | | 3.886 | 3.481 | 3.082 | 2.524 | |
| 1240 | | 3.877 | 3.474 | 3.074 | 2.518 | |
| 1250 | | 3.869 | 3.467 | 3.065 | 2.512 | |
| 1260 | | 3.861 | 3.460 | 3.057 | 2.506 | |
| 1270 | | 3.853 | 3.453 | 3.049 | 2.500 | |
| 1280 | 4.229 | 3.844 | 3.446 | 3.041 | 2.495 | 1.895 |
| 1290 | 4.221 | 3.836 | 3.439 | 3.032 | 2.489 | 1.889 |
| 1300 | 4.212 | 3.828 | 3.432 | 3.024 | 2.483 | 1.882 |
| 1310 | 4.204 | 3.820 | 3.425 | 3.016 | 2.477 | 1.876 |
| 1320 | 4.195 | 3.811 | 3.418 | 3.007 | 2.472 | 1.870 |
| 1330 | 4.186 | 3.803 | 3.411 | 2.999 | 2.466 | 1.864 |
| 1340 | 4.178 | 3.794 | 3.405 | 2.991 | 2.460 | 1.858 |

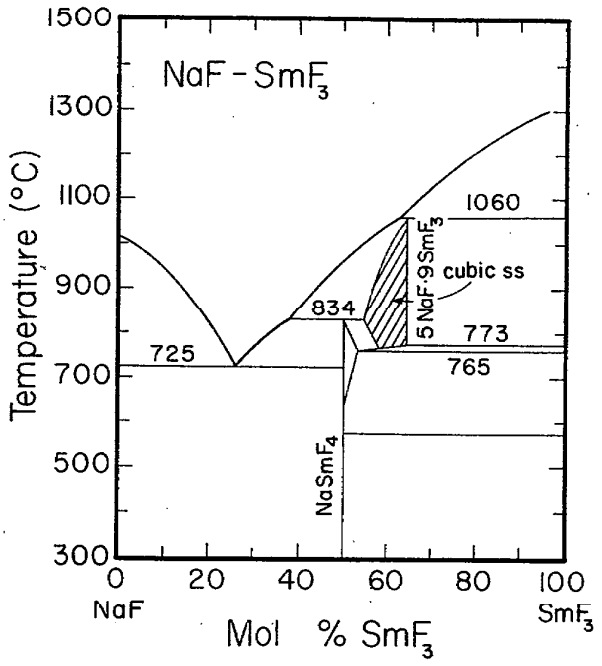


FIGURE 46. Temperature-composition phase diagram for $NaF$-$SmF_3$.
R. E. Thoma, H. Insley, and G. M. Herbert, Inorg. Chem., 5 [7], 1224 (1966).

TABLE 184 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % $SmF_3$) | $a$ | $b.10^4$ | Stand. deviation [87, 98] |
|---|---|---|---|
| 0.0 | 2.682 | −6.151 | 0.00239 |
| 10.0 | 3.233 | −5.764 | 0.0107 |
| 20.0 | 4.101 | −8.282 | 0.0085 |
| 30.0 | 4.335 | −6.943 | 0.0113 |
| 40.0 | 4.901 | −8.255 | 0.0191 |
| 50.0 | 5.324 | −8.553 | 0.0130 |

References: [87] and [98] (for NaF). Data reported in equation form. Two-dimensional statistical analysis was unsuccessful.

## $NaF$-$SrF_2$

### Electrical Conductance

The recommended values in table 186 are based on the work of Thompson and Kaye (classical ac technique) [111].

TABLE 185 A. Investigations critically re-examined

| Ref. | $SrF_2$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 111 | 40.1 | 1173–1373 |
| 100* | 40.1 | 1173, 1273, 1373 |

* Data from reference [111].

TABLE 185 B. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) | Calibration |
|---|---|---|---|
| Pt crucible [111] | Pt [111] | 1000 [111] | Molten $KNO_3$ [111] |

### Melt Preparation and Purification

Thompson and Kaye [111] used analyzed chemical reagents (J. T. Baker Chemical Co.) without further purification.

TABLE 186 a. $NaF–SrF_2$: Electrical conductance

Specific conductance: Numerical values ($ohm^{-1}$ $cm^{-1}$)

| $T$ | 40.1 Mol % $SrF_2$ |
|---|---|
| 1180 | 4.489 |
| 1200 | 4.609 |
| 1220 | 4.729 |
| 1240 | 4.850 |
| 1240 | 4.970 |
| 1280 | 5.091 |
| 1300 | 5.211 |
| 1320 | 5.332 |
| 1340 | 5.452 |
| 1360 | 5.573 |

TABLE 186 b. Temperature-dependent equations

$\kappa = a + bT$ ($ohm^{-1}$ $cm^{-1}$)

| Comp. (mol % $SrF_2$) | $a$ | $b \cdot 10^3$ | Stand. error of est. |
|---|---|---|---|
| 40.1 | −2.6174 | 6.0220 | 0.058 |

Reference: [111]. Data reported in numerical form.

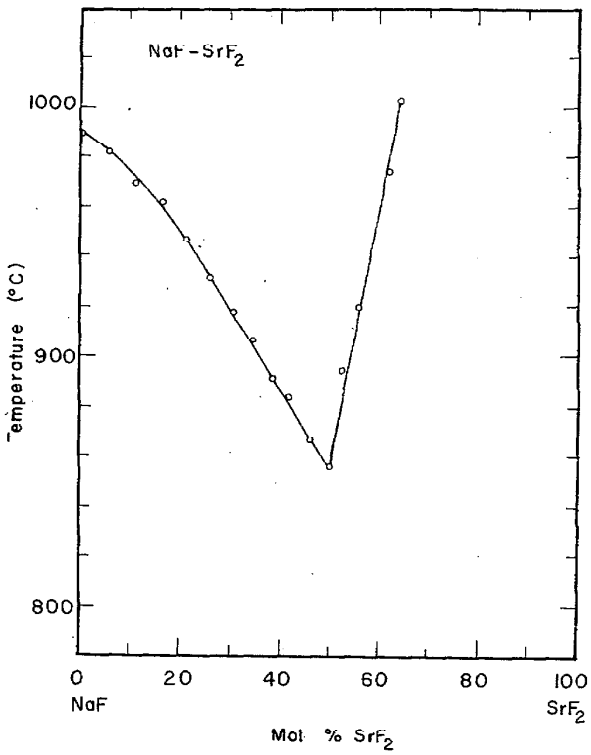


FIGURE 47. Temperature-composition phase diagram for $NaF-SrF_2$. G. A. Bukhalova, Izv. Sekt. Fiz. Khim. A., 26, 138 (1955).

## $NaF-ThF_4$

### Electrical Conductance

The recommended values in table 189 are based on the work of Brown and Porter (classical ac technique) [24].

TABLE 187 A. Investigations critically re-examined

| Ref. | $ThF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 24 | 0–50 | 1073–1363 |
| 100* | 12, 33, 50 | 1073–1363 |
| 87 | 0–50 | 1073–1343 |

*Data from reference [24].

TABLE 187 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $ThF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| **24** | 1 | 3 | 0 | 5.5 | (1310) | 8.3 | (1360) |
| 87 | 1 | 3 | 0 | 5.5 | (1310) | 8.3 | (1360) |

TABLE 187 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) | Calibration |
|---|---|---|---|
| Boron nitride cylinders with graphite jackets, melt contained in graphite crucible [24, 87] | Mo tubes [24, 87] | 1000–20,000 experimental values at 10,000 [24]<br><br>20–20,000 experimental values at 10,000 [87] | Molten KCl [24] |

Comments: Remarks concerning references [24] and [87] are discussed under the LiF-$UF_4$ and $CaF_2$-LiF systems, respectively.

Electrical Conductivity values reported by Porter, Meaker and Kesterke [87] are identical to the earlier values of Porter and Brown [24].

## Density

The recommended values in table 190 are based on the work of Porter and Meaker (Archimedean method) [98].

TABLE 188 A. Investigations critically re-examined

| Ref. | $ThF_4$ (mol %) | Temp. range (T) |
|---|---|---|
| 24 | 0–50 | 1073–1363 |
| 87 | 0–50 (graphical) | 1273 |
| **98** | 0, 12, 20, 33, 40, 50 | 1073–1353 |

TABLE 188 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $ThF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| 24 | 4.1 | 98 | 50 | 2.9 | (1073) | 3.1 | (1353) |
| 24 | 4.1 | 98 | 40 | 3.0 | (1113) | 3.2 | (1353) |
| 24 | 4.1 | 98 | 33 | 2.8 | (1093) | 3.0 | (1353) |
| 24 | 4.1 | 98 | 20 | 2.7 | (1123) | 2.8 | (1343) |
| 24 | 4.1 | 98 | 12 | 2.6 | (1173) | 2.7 | (1343) |
| 24 | 4.1 | 98 | 0 | 1.7 | (1340) | 2.4 | (1280) |
| 24 | 1.1 | 3 | 0 | 0.0 | (1330) | 0.5 | (1360) |
| **98** | 1.1 | 3 | 0 | −2.2 | (1280) | −2.5 | (1340) |

TABLE 188 C. Cell Materials and Calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [24, 87, 98] | Molten KCl [24, 87, 98] |

Comment: The density measurements of molten KCl in the temperature range 810 to 975 ° C for references [24] and [98] agreed with the published values of Van Artsdalen and Yaffe (NSRDS-NBS-15, Molten Salts: Vol. 1, reference 79) to within an average deviation of ±0.4 percent and ±0.3 percent, respectively.

Density values were initially reported by Brown and Porter [24] and then by Porter and Meaker [98]. The more recent measurements [98] were made with an improved apparatus involving a more precise control of the immersed volume of the plummet. Density values [98] were reported in the form of linear temperature-dependent equations with standard deviations in the range: $2.39\times10^{-3}$ gcm$^{-3}$ (0 mol % $ThF_4$) to $22.5\times10^{-3}$ gcm$^{-3}$ (40 mol % $ThF_4$).

## Melt Preparation and Purification

The procedure used by Brown and Porter [24] is discussed under the LiF-$ThF_4$ system.

The method of Porter and Meaker [98] is discussed under the system $CaF_2$-LiF.

TABLE 189 a. $NaF-ThF_4$: Electrical conductance

Specific conductance: Numerical values (ohm $^{-1}$ cm$^{-1}$)

Mol percent $ThF_4$

| $T$ | 50.0 | 40.0 | 33.0 | 20.0 | 12.0 | 0 |
|---|---|---|---|---|---|---|
| 1080 | 1.52 | 1.66 | 1.79 | 2.45 | | |
| 1090 | 1.57 | 1.70 | 1.83 | 2.49 | | |
| 1100 | 1.62 | 1.74 | 1.87 | 2.53 | | |
| 1110 | 1.68 | 1.77 | 1.91 | 2.56 | | |
| 1120 | 1.73 | 1.81 | 1.95 | 2.60 | | |
| 1130 | 1.78 | 1.85 | 1.98 | 2.64 | | |
| 1140 | 1.83 | 1.88 | 2.02 | 2.68 | | |
| 1150 | 1.88 | 1.92 | 2.06 | 2.71 | | |
| 1160 | 1.94 | 1.96 | 2.10 | 2.75 | | |
| 1170 | 1.99 | 1.99 | 2.14 | 2.79 | | |
| 1180 | 2.04 | 2.03 | 2.18 | 2.83 | 3.51 | |
| 1190 | 2.09 | 2.07 | 2.22 | 2.86 | 3.55 | |
| 1200 | 2.15 | 2.10 | 2.26 | 2.90 | 3.58 | |
| 1210 | 2.20 | 2.14 | 2.29 | 2.94 | 3.62 | |
| 1220 | 2.25 | 2.18 | 2.33 | 2.98 | 3.66 | |
| 1230 | 2.30 | 2.21 | 2.37 | 3.01 | 3.70 | |
| 1240 | 2.36 | 2.25 | 2.41 | 3.05 | 3.73 | |
| 1250 | 2.41 | 2.29 | 2.45 | 3.09 | 3.77 | |
| 1260 | 2.46 | 2.32 | 2.49 | 3.13 | 3.81 | |
| 1270 | 2.51 | 2.36 | 2.53 | 3.16 | 3.84 | |
| 1320 | | | | | | 5.38 |
| 1340 | | | | | | 5.50 |
| 1360 | | | | | | 5.61 |

TABLE 190 a. $NaF-ThF_4$: Density

Numerical values (gcm$^{-3}$)

Mol percent $ThF_4$

| $T$ | 50.0 | 40.0 | 33.0 | 20.0 | 12.0 | 0.0 |
|---|---|---|---|---|---|---|
| 1080 | 5.092 | | | | | |
| 1095 | 5.080 | | 4.102 | | | |
| 1110 | 5.068 | | 4.087 | | | |
| 1125 | 5.056 | 4.509 | 4.071 | 3.306 | | |
| 1140 | 5.043 | 4.488 | 4.055 | 3.297 | | |
| 1155 | 5.031 | 4.468 | 4.040 | 3.287 | | |
| 1170 | 5.019 | 4.447 | 4.024 | 3.277 | | |
| 1185 | 5.007 | 4.427 | 4.009 | 3.267 | 2.861 | |
| 1200 | 4.995 | 4.406 | 3.993 | 3.258 | 2.848 | |
| 1215 | 4.982 | 4.386 | 3.977 | 3.248 | 2.835 | |
| 1230 | 4.970 | 4.366 | 3.962 | 3.238 | 2.822 | |
| 1245 | 4.958 | 4.345 | 3.946 | 3.228 | 2.809 | |
| 1260 | 4.946 | 4.325 | 3.931 | 3.218 | 2.796 | |
| 1275 | 4.933 | 4.304 | 3.915 | 3.209 | 2.783 | 1.898 |
| 1290 | 4.921 | 4.284 | 3.899 | 3.199 | 2.770 | 1.889 |
| 1305 | 4.909 | 4.263 | 3.884 | 3.189 | 2.757 | 1.879 |
| 1320 | 4.897 | 4.243 | 3.868 | 3.179 | 2.744 | 1.870 |
| 1335 | 4.884 | 4.222 | 3.853 | 3.170 | 2.732 | 1.861 |
| 1350 | 4.872 | 4.202 | 3.837 | 3.160 | 2.719 | 1.852 |

TABLE 189 b. Temperature-dependent equations

$\kappa = a + bT$ (ohm$^{-1}$ cm$^{-1}$)

| Comp. (mol % $ThF_4$) | $a$ | $b \cdot 10^3$ |
|---|---|---|
| 0 | −2.06 | 5.64 |
| 12.0 | −0.90 | 3.74 |
| 20.0 | −1.61 | 3.76 |
| 33.0 | −2.40 | 3.88 |
| 40.0 | −2.29 | 3.66 |
| 50.0 | −4.13 | 5.23 |

Reference: [24]. Data reported in equation form.

TABLE 190 b. Temperature-dependent equations

$\rho = a + bT$ (gcm$^{-3}$)

| Comp. (mol % $ThF_4$) | $a$ | $b \cdot 10^4$ | Stand. dev. [98] |
|---|---|---|---|
| 0.0 | 2.682 | −6.151 | 0.0024 |
| 12.0 | 3.881 | −8.610 | 0.0120 |
| 20.0 | 4.039 | −6.512 | 0.0198 |
| 33.0 | 5.241 | −10.400 | 0.0100 |
| 40.0 | 6.042 | −13.630 | 0.0225 |
| 50.0 | 5.973 | −8.154 | 0.0156 |

Reference: [98]. Data reported in equation form. Two-dimensional statistical analysis was unsuccessful.

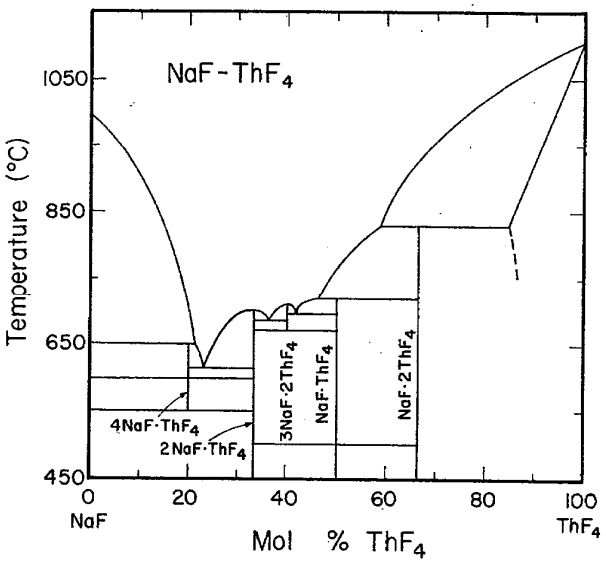


FIGURE 48. Temperature-composition phase diagram for NaF-$ThF_4$.
R. E. Thoma, H. Insley, B. S. Landau, H. A. Friedman, and W. R. Grimes, J. Phys. Chem., **63**, 1269 (1959).

## $NaF-UF_4$

### Electrical Conductance

The recommended values in table 194 are based on the work of Brown and Porter (classical ac technique) [**24**].

TABLE 191 A. Investigations critically re-examined

| Ref. | $UF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| **24** | 0–75 | 973–1363 |
| 100* | 15, 35, 75 | 973–1363 |
| 87 | 0–75 | 973–1343 |

*Data from reference [**24**].

Table 191 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $UF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| **24** | 1 | 3 | 0 | 5.5 | (1310) | 8.3 | (1360) |

TABLE 191 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) | Calibration |
|---|---|---|---|
| Boron nitride cylinders with graphite jackets, melt contained in a graphite crucible [**24**, 87] | Mo tubes [**24**, 87] | 1000–20,000 experimental values at 10,000 [**24**]<br>20–20,000 experimental values at 10,000 [87] | Molten KCl [**24**] |

Comments: Remarks concerning references [**24**] and [87] are discussed under the LiF–$UF_4$ and $CaF_2$–LiF systems, respectively.

Electrical conductivity values reported by Porter, Meaker, and Kesterke [87] are identical to the earlier values of Porter and Brown [**24**].

### Density

The recommended values in table 195 are based on the work of Porter and Meaker (Archimedean method) [**98**].

TABLE 192 A. Investigations critically re-examined

| Ref. | $UF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 24 | 0–75 | 1073–1363 |
| 35 | 33.3 | |
| 87 | 0–75 (graphical) | 1273 |
| **98** | 0–75 | 1073–1353 |
| 19 | 24–70 | 873, 973, 1073 |
| 17 | 24–70 | 873, 973, 1073 |

TABLE 192 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $UF_4$ mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | ($T$) | % (max) | ($T$) |
| 24 | 4.1 | 100 | 75.0 | 2.8 | (1223) | 3.0 | (1323) |
| 24 | 4.1 | 100 | 54.7 | 2.9 | (1073) | 3.1 | (1353) |
| 24 | 4.1 | 100 | 35.0 | 2.7 | (1073) | 3.0 | (1353) |
| 24 | 4.1 | 100 | 15 | 3.1 | (1143) | 3.4 | (1303) |
| 24 | 4.1 | 100 | 0 | 1.7 | (1340) | 2.4 | (1280) |
| 24 | 1 | 3 | 0 | 0.0 | (1330) | 0.5 | (1360) |
| **98** | 1 | 3 | 0 | −2.2 | (1280) | −2.5 | (1340) |

TABLE 192 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Mo plummet connected to a quartz spring by a Mo wire, melt contained in a graphite crucible [24, 87, **98**]; Pt cylinder and suspension wire, In crucible [19, 17] | Molten KCl [24, 87, **98**] |

Comments: Brief remarks concerning references [24] and [**98**] are given under the system NaF-$ThF_4$. Density values in reference [**98**] were reported in the form of linear temperature-dependent equations with standard deviations in the range: $2.39\times10^{-3}$ gcm$^{-3}$ (0 mol % $UF_4$) to $36.0\times10^{-3}$ gcm$^{-3}$ (75 mol % $UF_4$).

## Viscosity

The recommended values in tables 196, 197 are based on the work of Cohen et al., (capillary and rotating cylinder methods [**35**]), and Blanke et al. (rotating cylinder method [**19**]).

TABLE 193 A. Investigations critically re-examined

| Ref. | $UF_4$ (mol %) | Temp. range ($T$) |
|---|---|---|
| **35** | 33.3 | 973, 1073, 1173 |
| 19 | 24–70 | 973, 1073 |

TABLE 193 B. Cell materials and calibration

| Cell material |
|---|
| Inner and outer cylinder of Inconel, Ni shaft and Mo torsion wire [**19**] |

## Melt Preparation and Purification

Materials used by Brown and Porter [**24**] are described under the system LiF-$ThF_4$.

The procedure used by Porter and Meaker [**98**] is discussed under the system $CaF_2$-LiF.

The preparation of pure NaF by Blanke et al. [19, 17] is given under the system $BeF_2$-NaF. Oxide impurities were removed from $ThF_4$ by vacuum heating in Ni crucibles at 750 °C with a HF gas flow over the melt. The melt was cooled to 150 °C and HF was removed by a flow of $H_2$ gas.

TABLE 194a. NaF-$UF_4$: Electrical conductance

Specific conductance: Numerical values (ohm$^{-1}$ cm$^{-1}$)

| | Mol percent $UF_4$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $T$ | 75.0 | 54.7 | 46.0 | 35.0 | 25.0 | 22.0 | 15.0 | 0 |
| 980 | | | | 1.40 | | 1.66 | | |
| 1000 | | | | 1.49 | | 1.74 | | |
| 1020 | | | | 1.58 | | 1.82 | | |
| 1040 | | | | 1.68 | | 1.90 | | |
| 1060 | | | 1.96 | 1.77 | | 1.98 | | |
| 1080 | | 2.02 | 2.04 | 1.86 | 1.90 | 2.07 | | |
| 1100 | | 2.10 | 2.12 | 1.96 | 1.99 | 2.15 | | |
| 1120 | | 2.18 | 2.20 | 2.04 | 2.07 | 2.23 | | |
| 1140 | | 2.25 | 2.28 | 2.14 | 2.16 | 2.30 | 2.88 | |
| 1160 | | 2.33 | 2.36 | 2.23 | 2.25 | 2.39 | 2.95 | |
| 1180 | 2.20 | 2.42 | 2.44 | 2.33 | 2.34 | 2.47 | 3.02 | |
| 1200 | 2.27 | 2.49 | 2.52 | 2.42 | 2.42 | 2.55 | 3.09 | |
| 1220 | 2.34 | 2.57 | 2.60 | 2.51 | 2.51 | 2.64 | 3.16 | |
| 1240 | 2.41 | 2.65 | 2.68 | 2.61 | 2.60 | 2.71 | 3.23 | |
| 1260 | 2.49 | 2.73 | 2.76 | 2.70 | 2.69 | 2.79 | 3.31 | |
| 1280 | 2.56 | 2.81 | 2.84 | 2.79 | 2.77 | 2.88 | 3.38 | |
| 1310 | | | | | | | | 5.33 |
| 1320 | | | | | | | | 5.38 |
| 1340 | | | | | | | | 5.50 |
| 1360 | | | | | | | | 5.61 |

TABLE 194 b. Temperature-dependent equations

$\rho = a + bT$ (ohm$^{-1}$ cm$^{-1}$)

| Comp. (mol % $UF_4$) | $a$ | $b\cdot10^3$ |
|---|---|---|
| 0 | −2.06 | 5.64 |
| 15.0 | −1.18 | 3.56 |
| 22.0 | −2.33 | 4.07 |
| 25.0 | −2.82 | 4.37 |
| 35.0 | −3.16 | 4.65 |
| 46.0 | −2.27 | 3.99 |
| 54.7 | −2.21 | 3.92 |
| 75.0 | −2.00 | 3.56 |

Reference: [24]. Data reported in equation form.

TABLE 195 a. NaF-$UF_4$: Density

Numerical values ($gcm^{-3}$)

Mol percent $UF_4$

| T | 75.0 | 54.7 | 46.0 | 35.0 | 22.0 | 15.0 | 0.0 |
|---|---|---|---|---|---|---|---|
| 1080 | | 5.430 | 4.988 | 4.357 | 3.739 | | |
| 1095 | | 5.401 | 4.970 | 4.337 | 3.725 | | |
| 1110 | | 5.373 | 4.953 | 4.317 | 3.711 | | |
| 1125 | | 5.344 | 4.935 | 4.296 | 3.697 | | |
| 1140 | | 5.316 | 4.918 | 4.276 | 3.683 | | |
| 1155 | | 5.287 | 4.900 | 4.256 | 3.669 | 3.252 | |
| 1170 | | 5.258 | 4.882 | 4.236 | 3.655 | 3.222 | |
| 1185 | | 5.230 | 4.865 | 4.215 | 3.641 | 3.193 | |
| 1200 | | 5.201 | 4.847 | 4.195 | 3.626 | 3.163 | |
| 1215 | 6.069 | 5.173 | 4.830 | 4.175 | 3.612 | 3.134 | |
| 1230 | 6.009 | 5.144 | 4.812 | 4.155 | 3.598 | 3.104 | |
| 1245 | 5.949 | 5.116 | 4.794 | 4.134 | 3.584 | 3.075 | |
| 1260 | 5.890 | 5.087 | 4.777 | 4.114 | 3.570 | 3.045 | |
| 1275 | 5.830 | 5.059 | 4.759 | 4.094 | 3.556 | 3.016 | 1.898 |
| 1290 | 5.770 | 5.030 | 4.742 | 4.074 | 3.542 | 2.986 | 1.889 |
| 1305 | 5.710 | 5.002 | 4.724 | 4.053 | 3.528 | 2.957 | 1.879 |
| 1320 | 5.651 | 4.973 | 4.706 | 4.033 | 3.514 | 2.928 | 1.870 |
| 1335 | 5.591 | 4.944 | 4.689 | 4.013 | 3.500 | 2.898 | 1.861 |
| 1350 | 5.531 | 4.916 | 4.671 | 3.993 | 3.486 | 2.869 | 1.852 |

TABLE 195 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % $UF_4$) | $a$ | $b \cdot 10^4$ | Stand. dev. [98] |
|---|---|---|---|
| 0.0 | 2.682 | −6.151 | 0.00239 |
| 15.0 | 5.520 | −19.640 | 0.0231 |
| 22.0 | 4.753 | −9.388 | 0.0180 |
| 35.0 | 5.815 | −13.500 | 0.0129 |
| 46.0 | 6.256 | −11.740 | 0.0200 |
| 54.7 | 7.485 | −19.030 | 0.0330 |
| 75.0 | 10.907 | −39.820 | 0.0360 |

Reference: [98]. Data reported in equation form. Two dimensional statistical analysis was unsuccessful.

TABLE 196. NaF–$UF_4$: Viscosity

Numerical values (cp)

Mol percent $UF_4$

| T | 70 | 60 | 54 | 46.16 | 42 | 37.5 | 33.33 | 25 | 24 |
|---|---|---|---|---|---|---|---|---|---|
| 973.2 | | 16.62 | 16.60 | 12.93 | 13.13 | 12.40 | 11.50 | | 12.25 |
| 1073.2 | 10.99 | 10.59 | 10.98 | 8.27 | 8.64 | 7.62 | 6.93 | 5.72 | 7.24 |

Reference: [19]. Due to limited data the numerical interpolated values reported in reference [19] are given.

TABLE 197. NaF–$UF_4$: Viscosity

Numerical values (cp)

| T | 33.3 Mol % $UF_4$ |
|---|---|
| 973.2 | 10.25 |
| 1073.2 | 7.0 |
| 1173.2 | 5.15 |

Reference: [35]. Due to limited data the experimental values are given.

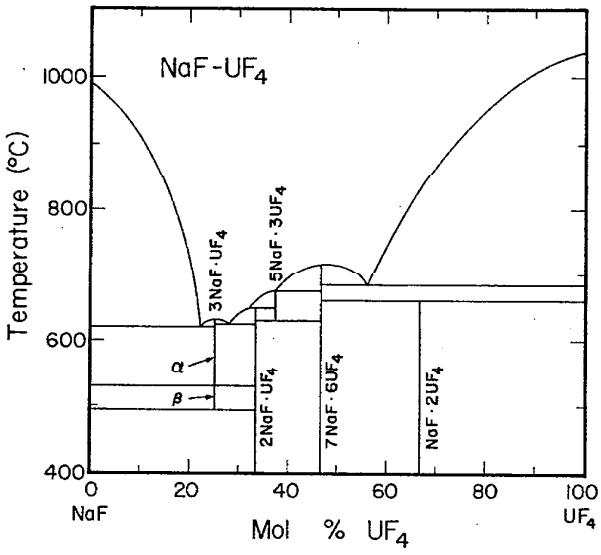


FIGURE 49. Temperature-composition phase diagram for NaF-$UF_4$. C. J. Barton, H. A. Friedman, W. R. Grimes, H. Insley, R. E. Moore, and R. E. Thoma, J. Amer. Ceram. Soc., 41 [2], 68 (1958).

## NaF-$YF_3$

### Electrical Conductance

The recommended values in table 200 are based on the work of Meaker, Porter, and Kesterke (classical ac technique) [87].

TABLE 198 A. Investigations critically re-examined

| Ref. | $YF_3$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 87 | 0, 10, 29, 32, 50 | 963–1343 |

TABLE 198 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $YF_3$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| 87 | 1 | 3 | 0 | 5.0 | (1300) | 7.4 | (1340) |

TABLE 198 C. Cell materials and calibration

| Cell material | Electrodes | Calibration |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 Hz measurements at 10,000 Hz [87] |

Comment: The specific conductance values measured in reference [87] were reported reproducible to ±1 percent. The precision of the measurements was ±3 percent. The measured resistance was found to be indepdendent of frequency over the range 20 to 20,000 hertz.

### Density

The recommended values in table 201 are based on the work of Porter and Meaker (Archimedean method) [98].

TABLE 199 A. Investigations critically re-examined

| Ref. | $YF_3$ (mol %) | Temp. range (T) |
|---|---|---|
| 87 | 0–50 (graphical) | 1273 |
| 98 | 0, 10, 20, 29, 32, 50 | 993–1353 |

TABLE 199 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $YF_3$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| 98 | 1 | 3 | 0 | −2.2 | (1270) | −2.5 | (1350) |

TABLE 199 C. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) |
|---|---|---|
| Capillary cell consisting of two boron nitride cylinders encased in a graphite jacket [87] | Mo [87] | 20–20,000 measurements at 10,000 [87] |

Comment: Brief remarks concerning reference [98] are given under the system $CaF_2$-LiF.

Density values [98] were reported in the form of linear temperature-dependent equations with standard deviations in the range: $7.05\times10^{-3}$ gcm$^{-3}$ (0 mol % $YF_3$) to $21.0\times10^{-3}$ gcm$^{-3}$ (50 mol % $YF_3$).

### Melt Preparation and Purification

The method used by Porter et al. [87, 98] is described under the system $CaF_2$-LiF. Yttrium fluoride contained less than 0.1 weight-percent of metallic impurities.

TABLE 200 a. NaF-$YF_3$: Electrical conductance

Specific conductance: Numerical values (ohm$^{-1}$ cm$^{-1}$)

Mol percent $YF_3$

| T | 50.0 | 32.0 | 29.0 | 20.0 | 10.0 | 0.0 |
|---|---|---|---|---|---|---|
| 980 | | 1.51 | 1.59 | | | |
| 1000 | | 1.59 | 1.69 | | | |
| 1020 | | 1.68 | 1.78 | | | |
| 1040 | | 1.77 | 1.88 | | | |
| 1060 | | 1.86 | 1.98 | | | |
| 1080 | | 1.95 | 2.07 | | | |
| 1100 | | 2.03 | 2.17 | 2.67 | | |
| 1120 | | 2.12 | 2.27 | 2.75 | | |
| 1140 | | 2.21 | 2.36 | 2.84 | | |
| 1160 | | 2.30 | 2.46 | 2.92 | | |
| 1180 | 1.89 | 2.39 | 2.56 | 2.00 | | |
| 1200 | 1.98 | 2.48 | 2.66 | 3.09 | | |
| 1220 | 2.07 | 2.56 | 2.75 | 3.17 | 3.99 | |
| 1240 | 2.16 | 2.65 | 2.85 | 3.25 | 4.07 | |
| 1260 | 2.25 | 2.74 | 2.95 | 3.33 | 4.14 | |
| 1280 | 2.34 | 2.83 | 3.04 | 3.42 | 4.21 | |
| 1300 | 2.44 | 2.92 | 3.14 | 3.50 | 4.29 | |
| 1320 | 2.53 | 3.00 | 3.24 | 3.58 | 4.36 | 5.39 |
| 1340 | 2.62 | 3.09 | 3.33 | 3.67 | 4.43 | 5.50 |

TABLE 200 b. Temperature-dependent equations

$\kappa = a + bT$ ($ohm^{-1}\ cm^{-1}$)

| Comp. (mol % $YF_3$) | $a$ | $b \cdot 10^3$ | Stand. deviations [87] |
|---|---|---|---|
| 0.0 | −2.060 | 5.640 | 0.0660 |
| 10.0 | −0.516 | 3.694 | 0.0116 |
| 20.0 | −1.895 | 4.150 | 0.0150 |
| 29.0 | −3.159 | 4.845 | 0.030 |
| 32.0 | −2.815 | 4.408 | 0.0256 |
| 50.0 | −3.524 | 4.584 | 0.0360 |

Reference: [87]. Data reported in equation form.

TABLE 201 b. Temperature-dependent equations

$\rho = a + bT$ ($gcm^{-3}$)

| Comp. (mol % $YF_3$) | $a$ | $b \cdot 10^4$ | Stand. dev. [98] |
|---|---|---|---|
| 0.0 | 2.682 | −6.151 | 0.00239 |
| 10.0 | 3.239 | −7.947 | 0.00870 |
| 20.0 | 3.321 | −7.071 | 0.00956 |
| 29.0 | 3.455 | −6.178 | 0.0103 |
| 32.0 | 3.779 | −8.110 | 0.00760 |
| 50.0 | 4.487 | −9.957 | 0.0210 |

Reference: [98]. Data reported in equation form. Two-dimensional statistical analysis was unsuccessful.

TABLE 201 a. $NaF$-$YF_3$: Density

Numerical values ($gcm^{-3}$)

Mol percent $YF_3$

| $T$ | 50.0 | 32.0 | 29.0 | 20.0 | 10.0 | 0.0 |
|---|---|---|---|---|---|---|
| 1005 | | | 2.834 | | | |
| 1020 | | | 2.825 | | | |
| 1035 | | 2.940 | 2.816 | | | |
| 1050 | | 2.927 | 2.806 | | | |
| 1065 | | 2.915 | 2.797 | | | |
| 1080 | | 2.903 | 2.788 | | | |
| 1095 | | 2.891 | 2.779 | | | |
| 1110 | | 2.879 | 2.769 | 2.536 | | |
| 1125 | | 2.867 | 2.760 | 2.526 | | |
| 1140 | | 2.854 | 2.751 | 2.515 | | |
| 1155 | | 2.842 | 2.741 | 2.504 | | |
| 1170 | | 2.830 | 2.732 | 2.494 | | |
| 1185 | | 2.818 | 2.723 | 2.483 | | |
| 1200 | | 2.806 | 2.714 | 2.472 | | |
| 1215 | | 2.794 | 2.704 | 2.462 | 2.273 | |
| 1230 | 3.262 | 2.781 | 2.695 | 2.451 | 2.262 | |
| 1245 | 3.247 | 2.769 | 2.686 | 2.441 | 2.250 | |
| 1260 | 3.232 | 2.757 | 2.677 | 2.430 | 2.238 | |
| 1275 | 3.217 | 2.745 | 2.667 | 2.419 | 2.226 | 1.898 |
| 1290 | 3.203 | 2.733 | 2.658 | 2.409 | 2.214 | 1.889 |
| 1305 | 3.188 | 2.721 | 2.649 | 2.398 | 2.202 | 1.879 |
| 1320 | 3.173 | 2.708 | 2.640 | 2.388 | 2.190 | 1.870 |
| 1335 | 3.158 | 2.696 | 2.630 | 2.377 | 2.178 | 1.861 |
| 1350 | 3.143 | 2.684 | 2.621 | 2.366 | 2.166 | 1.852 |

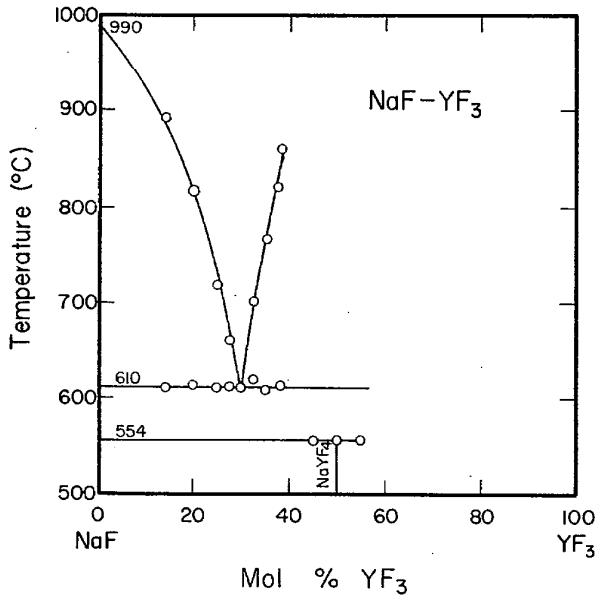


FIGURE 50. Temperature-composition phase diagram for $NaF$-$YF_3$. C. A. Bukhalova and E. P. Babaeva, Russ. J. Inorg. Chem., **11**, 349 (1966).

## $NaF-ZrF_4$

### Electrical Conductance

The recommended values in figure 51 were based on the work of Greene (classical ac technique and modified ac potentiometric method) [54].

TABLE 202 A. Investigations critically re-examined

| Ref. | $ZrF_4$ (mol %) | Temp. range (T) |
|---|---|---|
| 35* | 43, 50 | 866, 977, 1089 |
| 54 | 43, 50 (graphical) | 825–1227 |
| 100* | 43, 50 | 838, 1003, 1158 |
| 50 | 0–25 (graphical) | 1323 |

* Data from [54].

TABLE 202 B. Cell materials and calibration

| Cell material | Electrodes | Frequency range (Hz) | Calibration |
|---|---|---|---|
| BeO dip cell with melt in Pt crucible [54] | Pt [54] | 1000 (500 used with potentiometric method) [54] | KCl solution and molten KCl [54] |
| Boron nitride cell [50] | Inconel [50] | 20–20,000 (measurements at 20,000) [50] | Molten NaF and measured cell dimensions [50] |

Comment: Greene [54] used three conductivity cells in his investigation. A beryllium oxide dip-type cell and a low resistance platinum crucible cell were used in conjunction with an ac Wheatstone bridge. A current-potential cell consisting of Pt electrodes immersed in a Pt crucible was used with a modified ac potentiometric bridge. Conductivity values were reported to be accurate to ±10 percent.

Fontana and Winand [50] used a boron nitride cell of the type described by Yim and Feinleib [119].

### Density

The recommended values in table 206 and figure 52 are based on the work of Fontana and Winand (Archimedean method) [49].

TABLE 203 A. Investigations critically re-examined

| Ref. | $ZrF_4$ (mol %) | Temp. range (T) |
|---|---|---|
| 121 | 50 | |
| 35 | 50 | |
| 97 | 0–33.3 | 1173, 1273 |
| 49 | 0, 5, 10, 25 | 1253–1368 |

TABLE 203 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $ZrF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| 97 | 1 | 3 | 0 | −1.83 | (1273) | | |

TABLE 203 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Pt spherical bob [97] | |
| Pt −10% Rh bob and Pd alloy suspension wire [49] | Molten NaF [49] |

Comment: The density apparatus of Fontana and Winand [49] was calibrated with molten NaF using the values of Jaeger (Molten Salts: Vol. 1, reference 25) and Blander (Molten Salt Chemistry, Interscience, N.Y., 1964). The overall error was less than 0.2 percent.

### Viscosity

The recommended values in table 207 are based on the work of Cohen et al. (capillary and rotating-cylinder method) [35].

TABLE 204 A. Investigations critically re-examined

| Ref. | $ZrF_4$ (mol %) | Temp. range (T) |
|---|---|---|
| 102 | 50 | 873 |
| 35 | 47, 50 | 873, 973, 1073 |

Comment: Cohen [35] reported error limits of ±10 percent for his viscosity measurements.

### Surface Tension

The recommended values in table 208 are based on the work of Decroly, Fontana, and Winand (Wilhelmy slide plate method) [43].

TABLE 205 A. Investigations critically re-examined

| Ref. | $ZrF_4$ (mol %) | Temp. range (T) |
|---|---|---|
| 43 | 0–25 | 1213–1325 |

TABLE 205 B. Comparisons with previous recommendations

| Ref. | Recommended value | | $ZrF_4$ (mol %) | % Departure | | | |
|---|---|---|---|---|---|---|---|
| | Vol. | Page | | % (min) | (T) | % (max) | (T) |
| 43 | 2 | 56 | 0 | 4.4 | (1322) | 5.5 | (1319) |

TABLE 205 C. Cell materials and calibration

| Cell material | Calibration |
|---|---|
| Pt-10% Rh plate and melt contained in graphite crucible [43] | Water, 25 °C [43] |

Comment: Surface tension results [43] on molten KCl at 900 and 1000 °C differed from the recommended data of Dahl and Duke (Molten Salts: Vol. 2, reference 31a) by −9.5 percent and −10.6 percent, respectively.

### Melt Preparation and Purification

Winand et al. [43, 49, 50] dried pure NaF under vacuum at 180 °C. The $ZrF_4$ was sublimed and dried under vacuum at 180 °C.

TABLE 206 a. $NaF-ZrF_4$: Density

Numerical va'ues ($gcm^{-3}$)

Mol percent $ZrF_4$

| T | 25 | 20 | 15 | 10 | 5 | 0 |
|---|---|---|---|---|---|---|
| 1323.2 | 2.43 | 2.36 | 2.27 | 2.17 | 2.05 | 1.92 |

TABLE 206 b. Composition-dependent equations

$\rho = a + bx + cx^2$ ($gcm^{-3}$)

($x$: mol fraction $ZrF_4$)

| Temperature (T) | a | b | c |
|---|---|---|---|
| 1323.2 | 1.915 | 2.81 | −2.95 |

TABLE 206 c. Temperature-dependent equation

| Comp. (mol % $ZrF_4$) | a | $b \cdot 10^4$ | Temp. range (T) |
|---|---|---|---|
| 0 to 25 | 2.669 | −5.7 | ~1313 to ~1330 |

Reference: [49]. Data reported in equat on form.

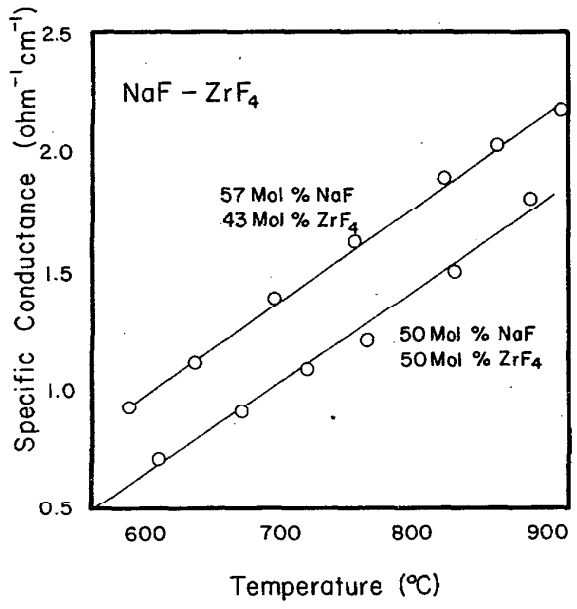


Figure 51. Plots [54] of specific conductance against temperature for the system $NaF-ZrF_4$.

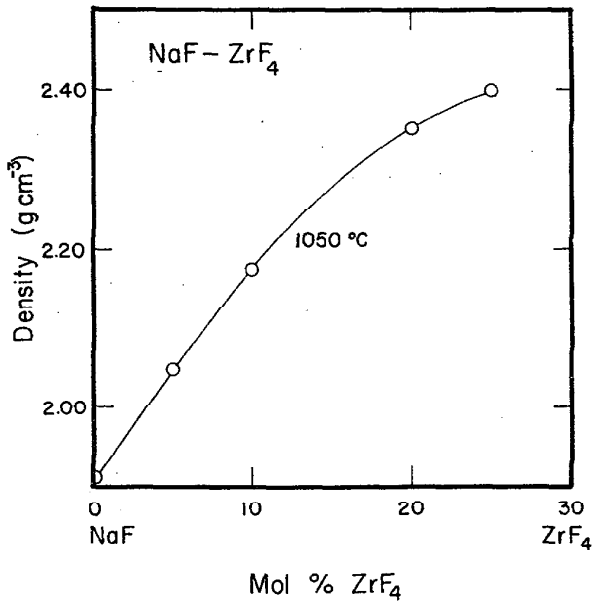


FIGURE 52. Isotherms [49] (°C) of density against molar composition for the system $NaF-ZrF_4$.

TABLE 207. $NaF\text{-}ZrF_4$: Viscosity

Numerical values (cp)

Mol percent $ZrF_4$

| $T$ | 50 | 47 |
|---|---|---|
| 873.2 | 2.60 | 7.5 |
| 973.2 | 1.66 | 4.6 |
| 1073.2 | 1.13 | 3.2 |

Reference: [35]. Due to limited data the experimental values are given.

TABLE 208. $NaF\text{-}ZrF_4$: Surface tension

Numerical values (dyn $cm^{-1}$)

Mol percent $ZrF_4$

| $T$ | 25 | 20 | 15 | 10 | 5 | 0 |
|---|---|---|---|---|---|---|
| 1213.2 | | | 162.8 | | | |
| 1222.2 | | | | 175.0 | | |
| 1284.2 | | 148.6 | | | | |
| 1316.2 | | | | | 175.0 | |
| 1318.2 | | | 155.4 | | | |
| 1319.2 | | 144.2 | | 164.8 | | |
| 1324.2 | 134.8 | | | | | |
| 1325.2 | | | | | | 186.3 |

Reference: [43]. Due to limited data the experimental values are given.

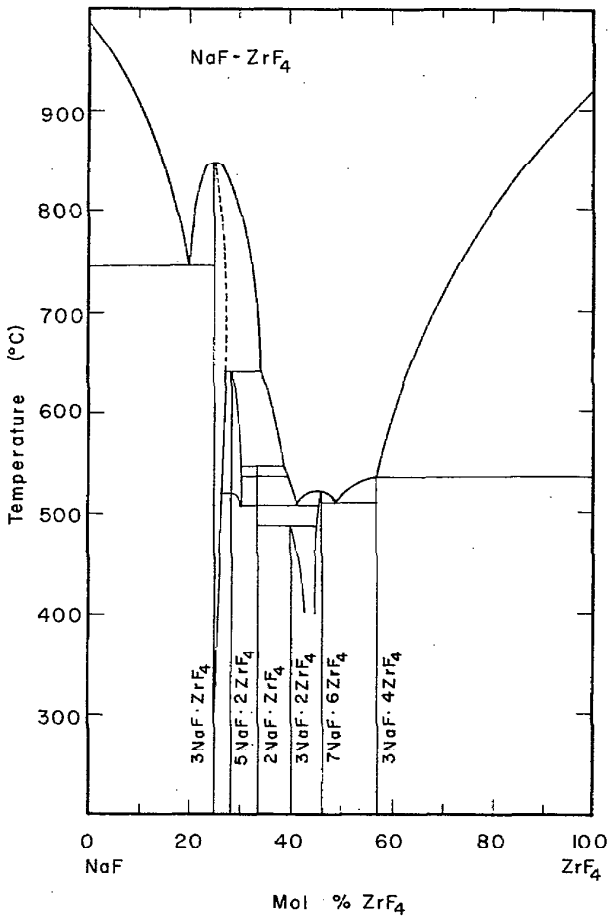


FIGURE 53. Temperature-composition phase diagram for $NaF\text{-}ZrF_4$. W. R. Grimes, D. R. Cuneo, F. F. Blankenship, G. W. Keilholtz, H. F. Poppendick, M. T. Robinson in "Fluid Fuel Reactors", by Lane, MacPherson, Maslaw, p. 570, chap. 12, 1958.

## $TiF_4$-$XeF_2$

### Electrical Conductance

The recommended values in figure 54 are based on the work of Rüdiger and Meinert (classical ac technique) [105].

TABLE 209A. Investigations critically re-examined

| Ref. | $XeF_2$ (mol %) | Temp. range ($T$) |
|---|---|---|
| 105 | ≅37–81 (graphical) | 405 |

TABLE 209B. Cell materials and electrodes

| Cell material | Electrodes |
|---|---|
| Quartz [105] | Pt [105] |

Comment: After three measurements the Pt electrodes were replaced due to attack by the melt.

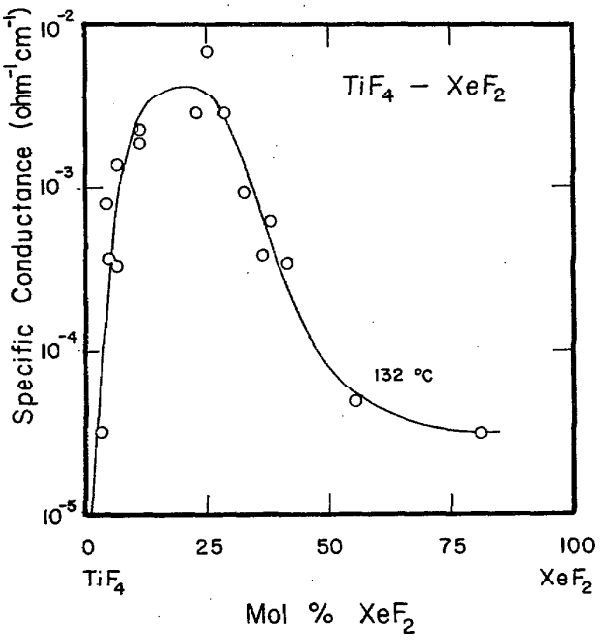


FIGURE 54. Isotherms [105] (°C) of specific conductance against molar composition for the system $TiF_4$-$XeF_2$.

## 6.2. General Summary Tables

TABLE 210. Total and recommended investigations [a]

| System | $\kappa$ | | $\rho$ | | $\eta$ | | $\gamma$ | |
|---|---|---|---|---|---|---|---|---|
| | No. of invest. | Recommended reference | No. of invest. | Recommended reference | No. of invest. | Recommended reference | No. of invest. | Recommended reference |
| $AlF_3$ -CsF | | | 2 | [25] | | | | |
| -KF | 4 | [120] | 2 | [74] | | | | |
| -LiF | 11 | [80] | 8 | [75, 95] | 1 | [108] | | |
| -NaF | 25 | [45, 46] | 21 | [75, 95] | 5 | [5] | 2 | [20] |
| -RbF | | | 2 | [25, 74] | | | | |
| $BaF_2$ -CsF | | | 1 | [26] | | | | |
| -KF | | | 1 | [26] | | | | |
| -LiF | | | 1 | [26] | | | | |
| -NaF | 3 | [111] | 2 | [7] | | | | |
| $BeF_2$ -KF | | | | | 3 | [35] | | |
| -LiF | 7 | [102] | 8 | [30, 33] | 7 | [33] | 3 | [109] |
| -NaF | 1 | [30] | 4 | [17] | 4 | [19, 35] | 1 | [72] |
| -RbF | | | 1 | [35] | 1 | [35] | | |
| $-UF_4$ | | | 1 | [18] | | | | |
| $CaF_2$ -LiF | 1 | [87] | 2 | [98] | | | | |
| -NaF | 3 | [111] | 1 | [7] | | | | |
| $CeF_3$ -KF | 1 | [87] | 2 | [98] | | | | |
| -LiF | 1 | [87] | 2 | [98] | | | | |
| -NaF | 1 | [87] | 2 | [98] | | | | |
| KF $-KBF_4$ | 1 | [611] | | | | | | |
| $-LaF_3$ | 1 | [87] | 2 | [98] | | | | |
| -LiF | 1 | [87] | 6 | [98] | | | 1 | [89] |
| -NaF | 2 | [87] | 3 | [98] | | | 1 | [89] |
| $-SmF_3$ | 1 | [87] | 1 | [98] | | | | |
| $-ThF_4$ | 1 | [87] | 2 | [98] | | | | |
| $-UF_4$ | 1 | [87] | 2 | [98] | | | | |
| $-YF_3$ | 1 | [87] | 2 | [98] | | | | |
| $-ZrF_4$ | 1 | [107] | 1 | [107] | 1 | [107] | 1 | [107] |
| $LaF_3$ -LiF | 1 | [87] | 2 | [98] | | | | |
| -NaF | 1 | [87] | 2 | [98] | | | | |
| LiF -NaF | 1 | [87] | 5 | [75] | 1 | [35] | 2 | [89] |
| -RbF | | | 1 | [35] | 1 | [35] | | |
| $-SmF_3$ | 1 | [87] | 1 | [87] | | | | |
| $-ThF_4$ | 3 | [24] | 4 | [60] | | | | |
| $-UF_4$ | 3 | [24] | 4 | [98] | 1 | [18] | | |
| $-YF_3$ | 1 | [87] | 2 | [98] | | | | |
| NaF $-NaBF_4$ | 2 | [125] | 2 | [123] | 2 | [123] | 1 | [124] |
| $-SmF_3$ | 1 | [87] | 1 | [87] | | | | |
| $-SrF_2$ | 2 | [111] | | | | | | |
| $-ThF_4$ | 3 | [24] | 3 | [98] | | | | |
| $-UF_4$ | 3 | [24] | 6 | [98] | 2 | [19, 35] | | |
| $-YF_3$ | 1 | [87] | 2 | [98] | | | | |
| $-ZrF_4$ | 4 | [54] | 4 | [49] | | | 1 | [43] |
| $TiF_4$ $-XeF_2$ | 1 | [105] | | | | | | |

[a] Total number of investigations and recommended references for specific conductance, density, viscosity, and surface tension of molten fluoride mixtures.

TABLE 211 a. References [a]

Specific conductance

| System | No. of invest. | Literature references |
|---|---|---|
| $AlF_3$ –KF | 4 | 14, 15, 100, **120** |
| –LiF | 11 | 6, 40, 41, 42, 77, 79, **80**, 84, 86, 100, 120 |
| –NaF | 25 | 5, 6, 10, 12, 14, 39, 40, 41, **45**, **46**, 51, 70, 77, 79, 80, 81, 82, 85, 86, 96, 104, 110, 114, 116, 120 |
| $BaF_2$ –NaF | 3 | 100, 110, **111** |
| $BeF_2$ –LiF | 7 | 22, 29, 30, 55, 57, 58, **102** |
| –NaF | 1 | **30** |
| $CaF_2$ –LiF | 1 | **87** |
| –NaF | 3 | 10, 100, **111** |
| $CeF_3$ –KF | 1 | **87** |
| –LiF | 1 | **87** |
| –NaF | 1 | **87** |
| KF –$KBF_4$ | 1 | **125** |
| –$LaF_3$ | 1 | **87** |
| –LiF | 1 | **87** |
| –NaF | 2 | 14, **87** |
| –$SmF_3$ | 1 | **87** |
| –$ThF_4$ | 1 | **87** |
| –$UF_4$ | 1 | **87** |
| –$YF_3$ | 1 | **87** |
| –$ZrF_4$ | 1 | **107** |
| $LaF_3$ –LiF | 1 | **87** |
| –NaF | 1 | **87** |
| LiF –NaF | 1 | **87** |
| –$SmF_3$ | 1 | **87** |
| –$ThF_4$ | 3 | **24**, 87 100 |
| –$UF_4$ | 3 | **24**, 87, 100 |
| –$YF_3$ | 1 | **87** |
| NaF –$NaBF_4$ | 2 | 124, **125** |
| –$SmF_3$ | 1 | **87** |
| –$SrF_2$ | 2 | 100, **111** |
| –$ThF_4$ | 3 | **24**, 87, 100 |
| –$UF_4$ | 3 | **24**, 87, 100 |
| –$YF_3$ | 1 | **87** |
| –$ZrF_4$ | 4 | 35, 50, **54**, 100 |
| $TiF_4$ –$XeF_2$ | 1 | **105** |

[a] Total number of investigations, recommended and literature references for specific conductance of molten fluoride mixtures.

TABLE 211 b. References [a]

Density

| System | No. of invest. | Literature references |
|---|---|---|
| $AlF_3$ –CsF | 2 | **25**, 74 |
| –KF | 2 | 25, **74** |
| –LiF | 8 | 74, **75**, 83, 84, 86, 94, **95**, 108 |
| –NaF | 21 | 4, 5, 7, 25, 45, 46, 52, 65, **75**, 83, 84, 85, 86, 92, 93, 94, **95**, 96, 103, 108, 115 |
| –RbF | 2 | **25**, 74 |
| $BaF_2$ –CsF | 1 | **26** |
| –KF | 1 | **26** |
| –LiF | 1 | **26** |
| –NaF | 2 | 7, 26 |
| $BeF_2$ –LiF | 8 | 18, 29, **30**, 32, **33**, 35, 57, 121 |
| –NaF | 4 | **17**, 19, 30, 35 |
| –RbF | 1 | **35** |
| –$UF_4$ | 1 | **18** |
| $CaF_2$ –LiF | 2 | 87, **98** |
| –NaF | 1 | **7** |
| $CeF_3$ –KF | 2 | 87, **98** |
| –LiF | 2 | 87, **98** |
| –NaF | 2 | 87, **98** |
| KF –$LaF_3$ | 2 | 87, **98** |
| –LiF | 6 | 35, 47, 48, 87, 89, **98** |
| –NaF | 3 | 87, 89, **98** |
| –$SmF_3$ | 1 | **87** |
| –$ThF_4$ | 2 | 87, **98** |
| –$UF_4$ | 2 | 87, **98** |
| –$YF_3$ | 2 | 87, **98** |
| –$ZrF_4$ | 1 | **107** |
| $LaF_3$ –LiF | 2 | 87, **98** |
| –NaF | 2 | 87, **98** |
| LiF –NaF | 5 | **75**, 87, 88, 89, 98 |
| –RbF | 1 | **35** |
| –$SmF_3$ | 1 | **87** |
| –$ThF_4$ | 4 | 24, **60**, 87, 98 |
| –$UF_4$ | 4 | 18, 24, 87, **98** |
| –$YF_3$ | 2 | 87, **98** |
| NaF –$NaBF_4$ | 2 | 122, **123** |
| –$SmF_3$ | 1 | **87** |
| –$ThF_4$ | 3 | 24, 87, **98** |
| –$UF_4$ | 6 | 17, 19, 24, 35, 87, **98** |
| –$YF_3$ | 2 | 87, **98** |
| –$ZrF_4$ | 4 | 35, **49**, 97, 121 |

[a] Total number of investigations, recommended and literature references for density of molten fluoride mixtures.

TABLE 211 c. References [a]

Viscosity

| System | No. of invest. | Literature references |
|---|---|---|
| $AlF_3$ –LiF | 1 | **108** |
| –NaF | 5 | **5**, 92, 93, 108, 117 |
| $BeF_2$ –KF | 3 | **35**, 36, 37 |
| –LiF | 7 | 18, 29, **33**, 35, 37, 68, 121 |
| –NaF | 4 | **19**, **35**, 56, 121 |
| –RbF | 1 | **35** |
| KF –$ZrF_4$ | 1 | **107** |
| LiF –NaF | 1 | **35** |
| –RbF | 1 | **35** |
| –$UF_4$ | 1 | **18** |
| NaF –$NaBF_4$ | 2 | 122, **123** |
| –$UF_4$ | 2 | **19**, **35** |

[a] Total number of investigations, recommended and literature references for viscosity of molten fluoride mixtures.

TABLE 211 d. References [a]

Surface tension

| System | No. of invest. | Literature references |
|---|---|---|
| $AlF_3$ –NaF | 2 | **5**, **20** |
| $BeF_2$ –LiF | 3 | 29, 68, **109** |
| –NaF | 1 | **109** |
| KF –LiF | 1 | **89** |
| –NaF | 1 | **89** |
| –$ZrF_4$ | 1 | **107** |
| Lif –NaF | 2 | 68, **89** |
| NaF –$NaBF_4$ | 1 | **124** |
| –$ZrF_4$ | 1 | **43** |

[a] Total number of investigations, recommended and literature references for surface tension of molten fluoride mixtures.

TABLE 212 a. Techniques

Specific conductance

A: Classical ac technique

B: Potentiometric ac technique

| System | Technique* | Recommended reference |
|---|---|---|
| $AlF_3$ –KF | A | **120** Yim and Feinleib |
| –LiF | A | **80** Matiasovsky et al. |
| –NaF | A | **45** Edwards et al. |
| $BaF_2$ –NaF | A | **111** Thompson and Kaye |
| $BeF_2$ –LiF | A | **102** Robbins and Braunstein |
| –NaF | A | **30** Robbins and Braunstein |
| $CaF_2$ –LiF | A | **87** Meaker, Porter, and Kesterke |
| –NaF | A | **111** Thompson and Kaye |
| $CeF_3$ –KF | A | **87** Meaker, Porter, and Kesterke |
| –LiF | A | **87** Meaker, Porter, and Kesterke |
| –NaF | A | **87** Meaker, Porter, and Kesterke |
| KF –KBF | A | **125** Selivanov and Stender |
| –$LaF_3$ | A | **87** Meaker, Porter, and Kesterke |
| –LiF | A | **87** Meaker, Porter, and Kesterke |
| –NAF | A | **87** Meaker, Porter, and Kesterke |
| –$SmF_3$ | A | **87** Meaker, Porter, and Kesterke |
| –$ThF_4$ | A | **87** Meaker, Porter, and Kesterke |
| –$UF_4$ | A | **87** Meaker, Porter, and Kesterke |
| –$YF_3$ | A | **87** Meaker, Porter, and Kesterke |
| –$ZrF_4$ | A | **107** Sheiko |
| $LaF_3$ –LiF | A | **87** Meaker, Porter, and Kesterke |
| –NaF | A | **87** Meaker, Porter, and Kesterke |
| LiF –NaF | A | **87** Meaker, Porter, and Kesterke |
| –$SmF_3$ | A | **87** Meaker, Porter, and Kesterke |
| –$ThF_4$ | A | **24** Brown and Porter |
| –$UF_4$ | A | **24** Brown and Porter |
| –$YF_3$ | A | **87** Meaker, Porter, and Kesterke |
| NaF –$NaBF_4$ | A | **125** Selivanov and Stender |
| –$SmF_3$ | A | **87** Meaker, Porter, and Kesterke |
| –$SrF_2$ | A | **111** Thompson and Kaye |
| –$ThF_4$ | A | **24** Brown and Porter |
| –$UF_4$ | A | **24** Brown and Porter |
| –$YF_3$ | A | **87** Meaker, Porter, and Kesterke |
| –$ZrF_4$ | A and B used for Ref. **54**. B used for Ref. 35 | **54** Greene |
| $TiF_4$ –$YeF_4$ | A | **105** Rudigert and Meinert |

*The technique indicated applies to all references given for each system in tables 211 a–211 d.

TABLE 212 b. Techniques

Density

A: Archimedean method
B: Dilatometric method

| System | Technique* | Recommended reference |
|---|---|---|
| $AlF_3$ –CsF | A | **25** Mal'tsev and Bukhalova |
| –KF | A | **79** Mal'tsev and Bukhalova |
| –LiF | A | **75** Matiasovski et al. |
| –NaF | A | **75** Matiasovski et al. |
| –RbF | A | **25** Ma'tsev and Bukhalova |
| $BaF_2$ –CsF | A | **26** Bukhalova and Yagub'yan |
| –KF | A | **26** Bukhalova and Yagub'yan |
| –LiF | A | **26** Bukhalova and Yagub'yan |
| –NaF | A | **7** Abramov and Kozunov |
| $BeF_2$ –LiF | A and B used for Ref. **33** and **30** | **33** Cantor, Ward, and Moynihan |
| –NaF | A and B is used for Ref. **30** | **17** Blanke et al. |
| –RbF | A | **35** Cohen et al. |
| $-UF_4$ | A | **18** Blanke et al. |
| $CaF_2$ –LiF | A | **98** Porter and Meaker |
| –NaF | A | **7** Abramov and Kozunov |
| $CeF_3$ –KF | A | **98** Porter and Meaker |
| –LiF | A | **98** Porter and Meaker |
| –NaF | A | **98** Porter and Meaker |
| KF $-LaF_3$ | A | **98** Porter and Meaker |
| –LiF | A | **98** Porter and Meaker |
| –NaF | A | **98** Porter and Meaker |
| $-SmF_3$ | A | **87** Porter and Meaker |
| $-ThF_4$ | A | **98** Porter and Meaker |
| $-UF_4$ | A | **98** Porter and Meaker |
| $-YF_3$ | A | **98** Porter and Meaker |
| $-ZrF_4$ | A | **107** Sheiko |
| $LaF_3$ –LiF | A | **98** Porter and Meaker |
| –NaF | A | **98** Porter and Meaker |
| LiF –NaF | A | **75** Matiasovsky |
| –RbF | A | **35** Cohen and Jones |
| $-SmF_3$ | A | **87** Meaker, Porter, and Kesterke |
| $-ThF_4$ | A | **60** Hill, Cantor, and Ward |
| $-UF_4$ | A | **98** Porter and Meaker |
| $-YF_3$ | A | **98** Porter and Meaker |
| NaF $-NaBF_4$ | B | **123** Cantor |
| $-SmF_3$ | A | **87** Meaker, Porter, and Kesterke |
| $-ThF_4$ | A | **98** Porter and Meaker |
| $-UF_4$ | A | **98** Porter and Meaker |
| $-YF_3$ | A | **98** Porter and Meaker |
| $-ZrF_4$ | A | **49** Fontana and Winand |

* The technique indicated applies to all references given for each system in table 211a–211d.

TABLE 212 c. Techniques

Viscosity

A: Capillary technique

B: Oscillating sphere technique

C: Oscillating hollow cylinder technique

D: Rotational cylinder technique

| System | Technique | Recommended reference |
|---|---|---|
| $AlF_3$ –LiF | B **108** | **108** Vetyukov and Sipriya |
| –NaF | B **5**, 92, 93, 108 D 117 | **5** Abramov |
| $BeF_2$ –KF | A and D **35**, 36, 37 | **35** Cohen et al. |
| –LiF | D **18**, 29, 33, 68 A and D 102, 35, 37 | **33** Cantor, Ward and Moynihan |
| –NaF | D **19**, 56 | **35** Cohen et al. |
| | A and D **35**, 121 | **19** Blanke et al. |
| –RbF | A and D **35** | **35** Cohen et al. |
| KF $-ZrF_4$ | B **107** | **107** Sheiko |
| LiF –NaF | A and D **35** | **35** Cohen et al. |
| –RbF | A and D **35** | **35** Cohen et al. |
| $-UF_4$ | D **18** | **18** Blanke et al. |
| NaF $-NaBF_4$ | C **123** | **123** Cantor |
| $-UF_4$ | A and D **35** | **35** Cohen et al. |
| | D **19** | **19** Blanke et al. |

TABLE 212 d. Techniques

Surface tension

A: Maximum Bubble Pressure Method

B: Wilhelmy Slide Plate Method

| System | Technique* | Recommended reference |
|---|---|---|
| $AlF_3$ –NaF | A | **20** Bloom and Burrows |
| $BeF_2$ –LiF | A | **109** Sturm |
| –NaF | A | **72** MacPherson |
| KF –LiF | A | **89** Mellors and Senderoff |
| –NaF | A | **89** Mellors and Senderoff |
| $-ZrF_4$ | A | **107** Sheiko |
| LiF –NaF | A | **89** Mellors and Senderoff |
| NaF $-ZrF_4$ | B | **43** Decroly, Fontana, and Winand |

* The technique indicated applies to the references given for each system in tables 211a–211d.

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## 7. References

[1] Janz, G. J., Dampier, F. W., Lakshminarayanan, G. R., Lorenz, P. K., and Tomkins, R. P. T., "Molten Salts: Volume 1, Electrical Conductance, Density, and Viscosity Data", Nat. Stand. Ref. Data Ser., NBS (U.S.), 15, 139 pages (Oct. 1968).

[2] Janz, G. J., Lakshminarayanan, G. R., Tomkins, R. P. T., and Wong, J., "Molten Salts: Volume 2, Section 2, Surface Tension Data", Nat. Stand. Ref. Data Ser., NBS (U.S.), 28, 110 pages (Aug. 1969).

[3] Janz, G. J., Krebs, Ursula, Siegenthaler, H. F., and Tomkins, R. P. T., "Molten Salts: Volume 3, Nitrates, Nitrites, and Mixtures", J. Phys. Chem. Ref. Data, 1, No. 3, 581-746 (1972).

[4] Abramov, G. A., Legkie Metal., **51**, 27 (1936).

[5] Abramov, G. A., Vetyukov, M. M., Gupalova, I. P., Kostyukov, A. A., and Lozhkin, L. N., "Theoretical Basis of Electrometallurgy of Aluminum", Metallurgizdat, Moskau (1953).

[6] Abramov, G. A., and Kostyukov, A. A., Trudy Liningradskogo Politekhnicheskogo Instituta, **40**, 188 (1957).

[7] Abramov, G. A., and Kozunov, P. T., Trans. Leningrad Ind. Inst., **1**, 60 (1939).

[8] Argyriades, D., Ph.D. Thesis, Rheinisch-Westfaelischen Technischen Hochschule Aachen, Germany (1954).

[9] Arkhangel'skaya, V. A., Mikheev, B. G., Nikitinskaya, T. I., and Tyutin, M. S., Soviet Physics—Solid State, **9**, No. 2, 539 (1967).

[10] Arndt, K., and Kalass, W., Z. Elektrochem., **30**, 12 (1924).

[11] Bailey, R. A., and Janz, G. J., "The Chemistry of Non-Aqueous Solvents", Lagowski, J. J., ed., Vol. 1, Chap. 7 (Academic Press, New York, 1966).

[12] Bajcsy, J., Malinovsky, M., and Matiasovsky, K., Electrochim. Acta, **7**, 543 (1962).

[13] Balakir, E. A., Bushuev, Yu. G., and Kudryavtsev, Yu. V., Siberian Chemistry Journal, Consultants Bureau No. 2, 164 (1968).

[14] Batashev, K. P., Legkie Metal., No. 10, 48 (1936).

[15] Batashev, K., and Shurin, A., Metallurg (Leningrad) **10**, 67 (1935).

[16] Danielyan, E. R., and Belyaev, A. I. (M. V. Lomonosov Inst. Fine Chem. Technol., Moscow). Tr. Vses. Soveshch. po Fiz. Khim. Rasplavlen. Solei, 2nd, Kiev 1963, 88-94 (Pub. 1965) (Russ).

[17] Blanke, B. C., Bousquet, E. N., Jones, L. V., Murphy, E. L., and Vallee, R. E., U.S.A.E.C. Research and Development Report, Contract No. AT-33-1-GEN-53, MLM-1076, July 1958.

[18] Blanke, B. C., Bousquet, E. N., Curtis, M. L., and Murphy, E. L., U.S.A.E.C. Research and Development Report, Contract No. AT-33-1-GEN-53, MLM-1086, March 1959.

[19] Blanke, B. C., Foster, K. W., Jones, L. V., Jordan, K. C., and Murphy, E. L., U.S.A.E.C. Research and Development Report, Contract No. AT-33-1-GEN-53, MLM-1079, Sep. 1958.

[20] Bloom, H., and Burrows, B. W., "Electrochemistry", Proceedings of the first Australian Conf., Pergamon Press, pp. 882-888, 1964.

[21] Bockris, J. O'M., White, J. L., and Mackenzie, J. D. (eds.), "Physico-Chemical Measurements at High Temperatures" (Butterworths, London and Washington, D.C., 1959).

[22] Braunstein, J., and Robbins, G. D., "Molten Salts, Characterization and Analysis", Mamantov, G. (ed.), pp. 443-477, Marcel Dekker, New York, 1969.

[23] Bronstein, H. R., Dworkin, A. S., and Bredig, M. A., Chemistry Progress Report, ORNL-2983, Oak Ridge National Laboratory, p. 65, 1960.

[24] Brown, E. A., and Porter, B., U.S. Department of the Interior, Bureau of Mines, Report of Investigations 6500, 1964.

[25] Bukhalova, G. A., and Mal'tsev, V. T., Russ. J. Inorg. Chem., **11**, 215 (1966).

[26] Bukhalova, G. A., and Yagub'yan, E. S., Trans. from Izv. Akad. Nauk SSSR, Neorgan. Mat. **3**, 1096 (1967).

[27] Bukhalova, G. A., and Yagub'yan, E. S., Trans. from Zh. Prikl. Khim., **41**, 1861 (1968).

[28] Cantor, S., Rev. Sci. Instrum. **40**, 967 (1969).

[29] Cantor, S. (ed.), Cooke, J. W., Dworkin, A. S., Robbins, G. D., Thomas, R. E., and Watson, G. M., U.S.A.E.C. Report, Contract No. W-7405-eng-26, ORNL-TM-2316, Aug. 1968.

[30] Cantor, S., Gilpatrick, L. O., Robbins, G. D., and Braunstein, J., U.S.A.E.C. Semiannual Progress Report, Contract No. W-7405-eng-26, ORNL-4449, pp. 122-146, Feb. 1970.

[31] Cantor, S., Hill, D. G., and Ward, W. T., Inorg. Nucl. Chem. Letters, **2**, 15 (1966).

[32] Cantor, S., Moynihan, C. T., and Ward, W. T., Reactor Chemistry Division Annual Progress Report, Contract No. W-7405-eng-26, ORNL-4076, pp. 25-26, March 1967.

[33] Cantor, S., Ward, W. T., and Moynihan, C. T., J. Chem. Phys., **50**, 2874 (1969).

[34] Christie, W. H., Chemistry Progress Report, ORNL-2782, Oak Ridge National Laboratory, p. 59, 1959.

[35] Cohen, S. I., et al., U.S.A.E.C. Unclassified Report, ORNL-2150 (DEL), Oak Ridge National Laboratory, 1956.

[36] Cohen, S. I., and Jones, T. N., U.S.A.E.C. Unclassified Report, CF-55-11-28, Oak Ridge National Laboratory, Nov. 1955.

[37] Cohen, S. I., and Jones, T. N., U.E.A.E.C. Unclassified Report, CF-55-8-2 (DEL) 10FI, Oak Ridge National Laboratory, Aug. 1955.

[38] Corbett, J. D., and Duke, F. R., "Technique of Inorganic Chemistry", Jonassen, H. B., and Weisberger, A. (eds.), Vol. 1 (Wiley, Interscience, New York 1963).

[39] Cuthbertson, J. W., and Waddington, J., Trans. Faraday Soc., **32**, 745 (1936).

[40] Danek, V., Malinovsky, M., and Matiasovsky, K., Chem. Zvesti, **22**, 641 (1968).

[41] Danek, V., Malinovsky, M., and Matiasovsky, Chem. Zvesti, **22**, 707 (1968).

[42] Danek, V., Novak, J., and Malinovsky, M., Chem. Zvesti, **21**, 832 (1967).

[43] Decroly, C., Fontana, A., and Winand, R., J. Nucl. Mater., **27**, 36 (1968).

[44] Dumas, D., Grojotheim, K., Hoegdahl, B., and Oye, H. A., Acta. Chem. Scand., **24**, 510 (1970).

[45] Edwards, J. D., Taylor, C. S., Cosgrove, L. A., and Russell, A. S., J. Electrochem. Soc., **100**, 508 (1953).

[46] Edwards, J. D., Taylor, C. S., Russell, A. S., and Maranville, L. F., J. Electrochem. Soc., **99**, 527 (1952).
[47] Ellis, R. B., U.S.A.E.C. Final Report, Contract No. AT-(40-1)-2073, ORO 2073-12, April 1967.
[48] Ellis, R. B., U.S.A.E.C. Annual Progress Report, Contract No. AT-(40-1)-2073, Dec. 1957.
[49] Fontana, A., and Winand, R., J. Nucl. Mater., **35**, 82 (1970).
[50] Fontana, A., and Winand, R., J. Nucl. Mater., **35**, 73 (1970).
[51] Frank, W. A., and Foster, L. M., J. Phys. Chem., **64**, 310 (1960).
[52] Frank, W. B., and Foster, L. M., J. Phys. Chem., **64**, 95 (1960).
[53] Graves, A. D., Inman, D., and Hills, G. J., "Advances in Electrochemistry and Electrochem. Eng.", Vol. 4, p. 117 (1965).
[54] Greene, N. D., Unclassified Report No. CF-54-8-64 Oak Ridge National Laboratory, 1954.
[55] Grimes, W. R., Bohlman, E. G., McDuffie, H. F., and Watson, G. M., U.S.A.E.C. Annual Progress Report, Contract No. W-7405-eng-26, ORNL-4229, March 1968.
[56] Grimes, W. R., J. Nucl. Tech. **8**, 137 (1970).
[57] Grimes, W. R., Bohlman, E. G., McDuffie, H. F., and Watson, G. M., U.S.A.E.C. Annual Progress Report, Contract No. W-7405-eng-26, ORNL 4586, July 1970.
[58] Grimes, W. R., Bohlman, E. G., McDuffie, H. F., and Watson, G. M., U.S.A.E.C. Annual Progress Report, Contract No. W-7405-eng-26, ORNL 4400, Feb. 1970.
[59] Grjotheim, K., Malinovsky, M., Matiasovsky, K., Zuca, S., and Oye, H. A., J. Chim. Phys., Oct., 145 (1969).
[60] Hill, D. G., Cantor, S., and Ward, W. T., J. Inorg. Nucl. Chem., **29**, 241 (1967).
[61] Holm, J. L., Ph.D. Thesis, Univ. of Trondheim, Norway (1971).
[62] Jaeger, F. M., Z. anorg. Allg. Chem., **101**, 1 (1917).
[63] Janz, G. J., "Molten Salts Handbook", Academic Press, New York (1967).
[64] Janz, G. J., Wong, J., and Lakshminarayanan, Chem. Instrum., **1**, 261 (1969).
[65] Kameyama, N., and Naka, A., J. Soc. Chem. Ind. Japan **34**, 140 (1931).
[66] Karpachev, S., Zhur. Fiz. Khim., **6**, 1079 (1935).
[67] Kirshenbaum, A. D., and Cahill, J. A., J. Phys. Chem., **70**, 3037 (1966).
[68] Kreyger, P. J., Ward, W. T., Cantor, S., Kirslis, S. S., and Blankenship, F. F., U.S.A.E.C. Annual Progress Report, ORNL 3591, Jan. 1964.
[69] Kulifeev, V. K., and Panchishnyi, V. I., Izv. Vyssh. Ucheb. Zaved., Tsvet. Met., 14, 92 (1971).
[70] Landon, G. J., and Ubbelohde, A. R., Proc. Roy. Soc., **A240**, 160 (1957).
[71] Levin, E. M., Robbins, C. R., and McMurdie, H. F., "Phase Diagrams for Ceramists", Reser, M. K. (ed.), The American Ceramic Society, 1964, 1969.
[72] MacPherson, H. G., U.S.A.E.C. Report ORNL 3015, p. 83, July 1960.
[73] Mackenzie, J. D., J. Chem. Phys., **32**, 1150 (1960).
[74] Mal'tsev, V. T., and Bukhalova, G. A., J. Appl. Chem. (USSR) **40**, 521 (1967).
[75] Matiasovsky, K., Private communication, 1968.
[76] Matiasovsky, K., Danek, V., and Lillebuen, B., Electrochim. Acta, **17**, 463 (1972).
[77] Matiasovsky, K., Danek, V., and Malinovsky, M., J. Electrochem. Soc., **116**, 1381 (1969).
[78] Matiasovsky, K., Lillebuen, B., and Danek, V., Rev. Roum. Chim., **16**, 163 (1971).
[79] Matiasovsky, K., Malinovsky, M., and Danek, V., Private communication, 1968.
[80] Matiasovsky, K., Malinovsky, M., and Danek, V., Electrochim. Acta, **15**, 25 (1970).
[81] Matiasovsky, K., and Malinovsky, M., Electrochim. Acta, **11**, 1035 (1966).
[82] Matiasovsky, K., Malinovsky, M., and Ordzovensky, S., J. Electrochem. Soc., **111**, 973 (1964).
[83] Malinovsky, M., Paucirova, M., and Matiasovsky, K., Chem. Zvesti, **23**, 27 (1969).
[84] Matsushima, T., Yoshida, Y., and Takahashi, N., Denki Kagaku, **39**, 102 (1971).
[85] Mashovets, V. P., The Electrolytic Production of Aluminum, p. 44 (1951).
[86] Mashovets, V. P., and Petrov, V. I., J. Appl. Chem. (USSR) **32**, 1561 (1959).
[87] Meaker, R. E., Porter, B., and Kesterke, D. G., United States Department of the Interior, Report of Investigations 7528, 1971.
[88] Mellors, G. W., and Senderoff, S., J. Electrochem. Soc., **111**, 1355 (1964).
[89] Mellors, G. W., and Senderoff, S., "Electrcohemistry", Proceedings of the First Australian Conf., Pergamon Press, p. 578 (1964).
[90] Mellors, G. W., and Senderoff, S., J. Electrochem. Soc., **111**, 1355 (1964).
[91] Moynihan, C. T., and Cantor, S., J. Chem. Phys., **48**, 115 (1968).
[92] Murgulescu, J. G., and Zuca, S., Acad. Rep. Populare Romine, Stud. Cercet. Chim., **9**, 55 (1961).
[93] Nishihara, K., Matsumura, Y., Komatsu, K., and Noguchi, H., Suiyokai-Shi, **15**, 311 (1964).
[94] Paucirova, M., Matiasovsky, K., and Malinovsky, M., Rev. Roum. Chim., **15**, 201 (1970).
[95] Paucirova, M., Matiasovsky, K., and Malinovsky, M., Rev. Roum. Chim., **15**, 33 (1970).
[96] Pearson, T. G., and Waddington, J., Discuss. Faraday Soc., **1**, 307 (1947).
[97] Sheiko, I. N., Perks, O. F., and Pozdnyokov, Ukr. Khim. Zhur., **31**, 1055 (1965).
[98] Porter, B., and Meaker, R. E., United States Department of the Interior, Report of Investigations 6838, 1966.
[99] Reeves, R. D., and Janz, G. J., "Advances in Electrochemistry and Electrochem. Eng.", Vol. 5, p. 137 (1967).
[100] Robbins, G. D., U.S.A.E.C. Review, ORNL-TM-2180, March 1968.
[101] Robbins, G. D., J. Electrochem. Soc., **116**, 813 (1969).
[102] Robbins, G. D., and Braunstein, J., U.S.A.E.C. Semiannual Progress Report, Contract No. W-7405-eng-26, ORNL-4548, pp. 156-159, Aug. 1970.
[103] Rolin, M., Rev. Int. Hautes Temper. et Refract., **8**, 127 (1971).
[104] Rolin, M., Electrochim. Acta, **17**, 2293 (1972).
[105] Ruediger, S., and Meinert, H., Z. Chem., **9**, 434 (1969).
[106] Jaeger, F. M., and Kahn, J., Koninkl Ned. Akad. VN. Wetenschapen, Proc. Ser. B., **19**, 381 (1916).
[107] Sheiko, I. N., Tr. Vses. Sovesch. Fiz. Rasplav. Solei. 2nd Kiev 1963, p. 79 (1965).
[108] Sipriya, G. J., and Vetyukov, M. M., J. Appl. Chem. (USSR), **36**, 1849 (1962).
[109] Sturm, B. J., U.S.A.E.C. Quart. Progress Report, ORNL-2626, Oct. 1958.
[110] Taniuchi, K., Keikinzokii, **20**, 157 (1970).
[111] Thompson, M. Dekay, and Kaye, A. L., Trans. Electrochem. Soc., **67**, 169 (1935).
[112] Voskresenskaya, N. K. (ed.), "Handbook of Solid-Liquid Equilibria in Systems of Anhydrous Inorganic Salts", 2 Vol., Trans. from Russian, Israel Program for Scientific Translations, Jerusalem, 1970.
[113] White, D. W. G., Am. Soc. Metals, Trans. Quart., **55**, 751 (1962).
[114] Winterhager, H., and Werner, L., Forschungsberichte des Wirtschafts-und Verkehrsministeriums Nordheim-Westfalen, No. 438, Germany, 1957.

[115] Vayna, A., Alluminio, **19**, 541 (1950).
[116] Vayna, A., Alluminio, **19**, 215 (1950).
[117] Vayna, A., Alluminio, **19**, 133 (1950).
[118] Yagub'yan, E. S., and Bukhalova, G. A., Russ. J. Inorg. Chem., **13**, 1162 (1968).
[119] Yim, W. Y., and Feinleib, M., J. Electrochem. Soc., **104**, 622 (1957).
[120] Yim, E. W., and Feinleib, M., J. Electrochem. Soc., **104**, 626 (1957).
[121] Grimes, W. R., Cuneo, D. R., Blankenship, F. F., Keilholtz, G. W., Poppendick, H. F., and Robinson, M. T., "Fluid Fuel Reactors", Chapter 12, pp. 569–581, 1958.
[122] Rosenthal, M. W., Haubenreich, P. N., and Briggs, R. B., U.S.A.E.C. Report, Contract No. W–740S–eng–26, ORNL–4812, pp. 137–140, Aug. 1972.
[123] Rosenthal, M. W., Briggs, R. B., and Kasten, P. R., U.S.A.E.C. Semiannual Progress Report, Contract No. W–7405–eng–26, ORNL–4449, pp. 145–146, Feb. 1970.
[124] Cantor, S. (ed.), Cooke, J. W., Dworkin, A. S., Robbins, G. D., Thomas, R. E., and Watson, G. M., U.S.A.E.C. Report, Contract No. W–7405–eng–26, ORNL–TM–2316, pp. 14–37, Aug. 1968.
[125] Selivanov, V. G., and Stender, V. V., Zh. Neorg. Khim., **4**, 2058 (1959).