*Journal of Chemical Technology and Metallurgy, 60, 5, 2025, 741-748*

# SYNTHESIS AND PHYSICOCHEMICAL PROPERTIES OF NEW TRIPLE LUTETIUM TELLURITES

Aitolkyn Toibek, Kenzhebek Rustembekov

*Department of Inorganic and Technical Chemistry*
*NLC "Karagandy University of the name of Academician E.A. Buketov"*
*28Universitetskaya St., Karaganda, 100024, Kazakhstan*
*rustembekov_kt@mail.ru (K.R.)*

*Received 12 July 2024*
*Accepted 12 May 2025*
*DOI: 10.59957/jctm.v60.i5.2025.5*

## ABSTRACT

*New triple lutetium tellurites $LuMeFeTeO_6$ (Me - Sr, Ba) are synthesized using ceramic technology from oxides $Lu_2O_3$, $TeO_2$, $Fe_2O_3$, carbonates $SrCO_3$ and $BaCO_3$. Using X - ray phase analysis, we confirmed the individuality, and determined the types of syngony, unit cell parameters, X - ray and pycnometric densities of compounds. It has been confirmed that tellurites crystallize in the tetragonal system with a distorted perovskite structural type. Using dynamic calorimetry in the temperature range 298.15 - 673 K, we studied the isobaric heat capacities of tellurites and derived equations for the Cp(T) dependence. The standard heat capacity of new tellurites has been determined, establishing a fundamental constant. We have calculated temperature dependences of the thermodynamic functions $S^0$ (T), $H^0$ (T) - $H^0$ (298.15), $\Phi^{xx}$ (T). The study results are significant for inorganic and physical chemistry of oxide materials, as well as inorganic materials science. They can be utilized for inclusion in reference books and thermodynamic data banks.*

Keywords: *lutetium, ternary tellurites, X - ray phase analysis, heat capacity, thermodynamic functions.*

## INTRODUCTION

The creation of new materials with specified physicochemical properties and structure is a fundamental problem of modern materials science. Therefore, establishing the relationship between the composition, synthesis conditions, and, consequently, the structure, and then the properties of inorganic compounds is one of the main tasks. Mixed oxides with a perovskite-like structure are gaining interest due to their potential applications such as heterogeneous catalysts for oxidation reactions, materials for oxygen-selective membranes, electrodes for high-temperature electrochemical devices including solid oxide fuel cells, as well as their semiconductor and ferroelectric properties [1 - 4]. Among the various systems, oxide systems involving rare earth elements (REE) and tellurium are prominent [5, 6]. As a family of second-order Jahn-Teller "SOJT" cations, the lone pair cation ($Te^{4+}$) is a key element that can induce macroscopic non-centrosymmetric (NCS) structures [7]. Materials chemists are interested in crystalline materials with NCS structure due to their technologically important characteristics, such as nonlinear optical (NLO) properties, ferroelectricity, pyroelectricity and piezoelectricity [8]. To date, simple tellurites have already been quite well studied and characterized in detail. Thus, the traditional approach to developing new materials - creating compounds that are more complex in composition is implemented in the study of binary and ternary tellurite systems [9, 10]. In this regard, this work aims to synthesize and study the physicochemical properties of new ternary lutetium tellurites.

## EXPERIMENTAL

The synthesis of compounds is carried out using ceramic technology, taking into account stoichiometric amounts of $Lu_2O_3$ (extra pure grade), $TeO_2$ (chemically pure grade), carbonates $SrCO_3$ and $BaCO_3$ (pure for analysis) in terms of the final formula $LuMeFeTeO_6$ (Me - Sr, Ba) in the range temperatures 1073 - 1473 K. X - ray diffraction patterns of the synthesized compounds are obtained using an Empyrean powder diffractometer from PANalytical. The synthesis technique, X-ray phase analysis of the synthesized compounds, interpretation of the obtained X - ray patterns and identification of phases are like the previous work [9].

The heat capacity of the synthesized tellurites was analyzed by using dynamic calorimetry with a serial device IT - S - 400 within the temperature range of 298.15 - 673 K [11]. The operating principle of the calorimeter is based on the comparative method of a dynamic c-calorimeter with a heat meter.

The experiments are carried out in the mode of monotonic, close to linear heating of the sample with an average speed of ~ 0.1 K $s^{-1}$. In an experiment, we are determining the temperature dependence of the parameter under study. The device circuit allows temperature measurements to be taken at fixed points every 25 K. This is achieved using a direct current potentiometer and switch built into the device. Volume range is not less than $1\times10^7$ J $K^{-1}$ $m^{-3}$. The time required to carry out measurements over the entire temperature range and process experimental data is no more than 2.5 h. The errors in measuring heat capacity on the IT - S - 400 device do not exceed ± 10 % [11, 12].

The calibration of the device, determination of the heat capacity of the standard copper sample, calculations to determine the standard deviation ($\delta$, J $g^{-1}$ $K^{-1}$) for the averaged values of specific heat capacities, as well as the random component of the error ($\Delta$, J $mol^{-1}$ $K^{-1}$) for the averaged values of molar heat capacity were carried out according to the method given earlier in the work [13].

Satisfactory agreement with the described from Robie et al. [14], as well as with new literary data reported by Bodryakov et al. [15], the result of determining the standard heat capacity of $\alpha$ - $Al_2O_3$ ($C_p^0$, 298.15 = 76 J $mol^{-1}$ $K^{-1}$), indicates the reliability of the obtained values of heat capacity of the synthesized new tellurites.

## RESULTS AND DISCUSSION

The powder diffraction pattern is an individual characteristic of a crystalline substance. Diffraction patterns of the synthesized ternary lutetium tellurites are presented in Fig. 1.

The results of indexing the X - ray diffraction patterns of the synthesized ternary lutetium tellurites are given in Table 1.

The reliability and correctness of the indexing results

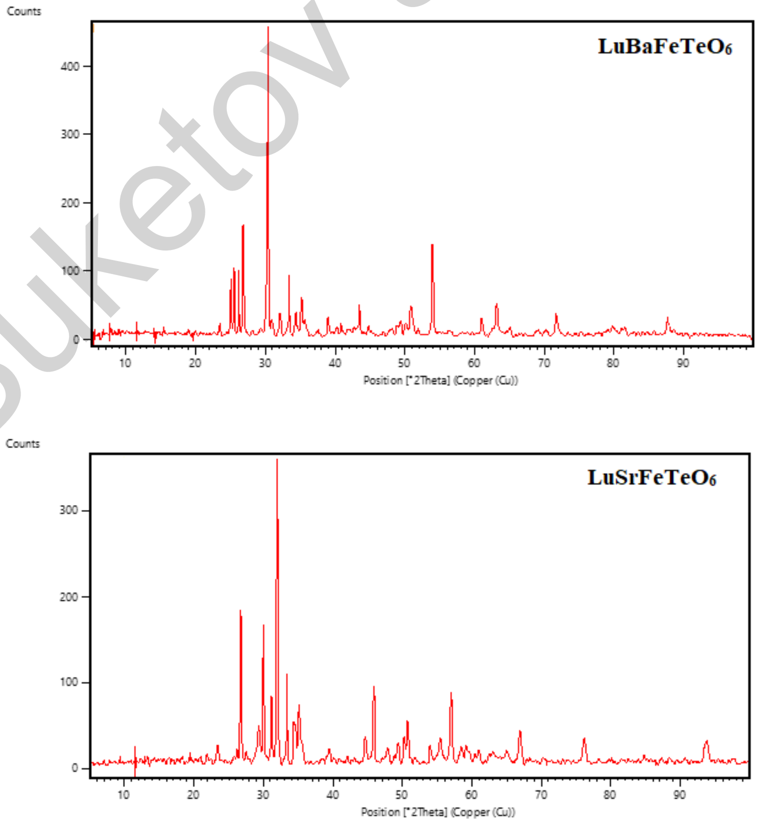


Fig. 1. X - ray diffraction patterns of tellurites $LuMeFeTeO_6$ (Me - Sr, Ba).

Table 1. Results of indexing X - ray diffraction patterns of tellurites $LuMeFeTeO_6$ (Me - Sr, Ba).

| h | k | l | 2Th. (c) [°] | 2Th. (o) [°] | d-sp. (c) [A] | d-sp. (o) [A] | $I/I_0$ |
|---|---|---|---|---|---|---|---|
| $LuSrFeTeO_6$ | | | | | | | |
| 3 | 1 | 0 | 23.3811 | 23.3823 | 3.801581 | 3.801394 | 5.98 |
| 3 | 2 | 0 | 26.7153 | 26.7486 | 3.334207 | 3.330134 | 47.83 |
| 1 | 1 | 2 | 29.2515 | 29.3112 | 3.050635 | 3.044558 | 12.48 |
| 3 | 2 | 1 | 30.0627 | 29.9975 | 2.970140 | 2.976454 | 43.38 |
| 2 | 0 | 2 | 31.1230 | 31.1624 | 2.871334 | 2.867790 | 21.99 |
| 2 | 1 | 2 | 32.0216 | 31.9983 | 2.792778 | 2.794754 | 100.00 |
| 4 | 2 | 0 | 33.3038 | 33.3766 | 2.688124 | 2.682430 | 28.95 |
| 3 | 3 | 1 | 34.4702 | 34.4462 | 2.599783 | 2.601545 | 13.31 |
| 3 | 0 | 2 | 35.4124 | 35.1059 | 2.532747 | 2.554154 | 19.40 |
| 4 | 3 | 1 | 39.9201 | 39.4577 | 2.256527 | 2.281899 | 3.46 |
| 4 | 4 | 1 | 44.8090 | 44.5595 | 2.021023 | 2.031761 | 7.18 |
| 6 | 1 | 0 | 45.8790 | 45.8009 | 1.976348 | 1.979534 | 22.06 |
| 6 | 2 | 0 | 47.8138 | 47.8232 | 1.900790 | 1.900441 | 4.53 |
| 5 | 2 | 2 | 49.4000 | 49.3597 | 1.843405 | 1.844819 | 6.36 |
| 3 | 2 | 3 | 49.9625 | 50.2171 | 1.823964 | 1.815312 | 8.27 |
| 5 | 4 | 1 | 50.5387 | 50.7149 | 1.804510 | 1.798654 | 13.55 |
| 7 | 1 | 0 | 53.8836 | 53.9342 | 1.700119 | 1.698645 | 5.92 |
| 7 | 0 | 1 | 55.2592 | 55.4330 | 1.661009 | 1.656211 | 8.16 |
| 6 | 4 | 1 | 56.9596 | 56.9645 | 1.615395 | 1.615266 | 23.03 |
| 2 | 0 | 4 | 58.4812 | 58.4622 | 1.576936 | 1.577404 | 2.21 |
| 2 | 1 | 4 | 59.0315 | 59.0574 | 1.563541 | 1.562919 | 0.86 |
| 7 | 0 | 2 | 60.8863 | 61.0040 | 1.520278 | 1.517627 | 3.15 |
| 6 | 0 | 3 | 62.9720 | 62.7818 | 1.474849 | 1.478858 | 0.43 |
| 6 | 2 | 3 | 65.0656 | 65.0398 | 1.432362 | 1.432869 | 2.68 |
| 4 | 2 | 4 | 66.9587 | 66.9541 | 1.396389 | 1.396474 | 9.79 |
| 8 | 5 | 1 | 76.0304 | 76.0467 | 1.250748 | 1.250520 | 7.66 |
| 2 | 2 | 6 | 93.7578 | 93.7699 | 1.055334 | 1.055229 | 6.83 |
| $LuBaFeTeO_6$ | | | | | | | |
| 0 | 0 | 3 | 25.3432 | 25.1958 | 3.511536 | 3.531743 | 5.16 |
| 2 | 2 | 0 | 26.0411 | 26.1758 | 3.418986 | 3.401697 | 20.40 |
| 2 | 1 | 2 | 26.6483 | 26.7317 | 3.342442 | 3.332200 | 32.81 |
| 3 | 1 | 1 | 30.4122 | 30.3287 | 2.936801 | 2.944695 | 100.00 |
| 3 | 2 | 0 | 33.3811 | 33.3698 | 2.682073 | 2.682958 | 12.79 |
| 3 | 2 | 1 | 34.4788 | 34.3236 | 2.599158 | 2.610556 | 6.53 |
| 1 | 0 | 4 | 35.2921 | 35.1356 | 2.541100 | 2.552058 | 12.48 |
| 2 | 2 | 4 | 43.3323 | 43.4671 | 2.086415 | 2.080254 | 10.19 |
| 2 | 2 | 5 | 50.8652 | 50.8719 | 1.793691 | 1.793469 | 8.98 |
| 5 | 2 | 2 | 53.8987 | 53.9179 | 1.699679 | 1.699118 | 26.80 |
| 1 | 1 | 7 | 63.2147 | 63.1239 | 1.469769 | 1.471664 | 8.39 |
| 0 | 0 | 8 | 71.6012 | 71.6718 | 1.316826 | 1.315703 | 6.69 |

*2Th. (c) [°] - calculated double Bragg reflection angle in degrees; 2Th. (o) [°] - experimental double Bragg reflection angle in degrees; d-sp. (c) [Å] - calculated interplanar distance; d-sp. (o) [Å] - experimental interplanar distance; [Å] - Angstrom.*

are confirmed by the satisfactory agreement between the experimental and calculated values of 2Th. and d - sp (Table 1) and the values of X - ray and pycnometric densities (Table 2).

The theoretical cell volumes of the synthesized tellurites are determined using the data on the cell volumes included in their composition, following a specific scheme:

$$V^{\circ}_{unit\ cell}\,LuMeFeTeO_6 = 0.5\,V^{\circ}_{unit\ cell}\,Lu_2O_3 + 0.5\,V^{\circ}_{unit\ cell}\,Fe_2O_3 + V^{\circ}_{unit\ cell}\,TeO_2 + V^{\circ}_{unit\ cell}\,MeO\ (\,Me - Sr,\ Ba) \qquad (1)$$

The accurate match of the calculated values for the volumes of basic units of tellurites with the sum of the volumes of basic units of the initial oxides of lutetium (+ 3), iron (+ 3), tellurium (+ 4), and strontium (barium) oxides, obtained from the Crystallography Open Database, along with the calculated cell volumes of compounds from X-ray data, further supports the accuracy of the X - ray patterns of the new tellurites [16]. So, for $LuSrFeTeO_6$ $V^0_{unit\ cell}$= 1029.03 Å$^3$ (from the sum of $V^0_{unit\ cell}$ oxides) and 944.19 ± 0.02 Å$^3$ (from indexing data), $LuBaFeTeO_6$ $V^0_{unit\ cell}$ = 1057.51 Å$^3$ (from the sum of $V^0_{unit\ cell}$ oxides) and 1048.40 ± 0.02 Å$^3$ (from indexing data).

We observe that as the ionic radii increase from Sr to Ba, the unit cell volumes of the synthesized tellurites also increase. Based on the indexing of X - ray diffraction patterns, it was found that $LuSrFeTeO_6$ and $LuBaFeTeO_6$ crystallize in a tetragonal system with lattice parameters as shown in Table 2.

As in the previous work [9], using the X'Pert HighScore Plus software package of the PANalytical diffractometer, the phase composition of new tellurites that crystallize in the distorted perovskite structural type was confirmed. When assigning compounds to the perovskite structure or to its distorted version, the "tolerance factor" t is considered [17]. Like presented by Rustembekov et al., the "tolerance factor" t for the synthesized lutetium tellurites was calculated [9]. The ionic radii of $Lu^{3+}$, $Sr^{2+,}$ $Ba^{2+}$, $Fe^{3+}$, $Te^{4+}$, $O^{2-}$ according to the classification of Shannon and Prewitt are borrowed [18]. As is known from Welles, for compounds with a perovskite-type structure, the "tolerance factor" t lies approximately in the range of 0.8 - 1.0 [17]. In our case, **t** for $LuSrFeTeO_6$ and $LuBaFeTeO_6$ are 0.88 and 0.94, respectively, which to a certain extent can be attributed to the perovskite structural type, confirming that these compounds can have semiconductor and ferroelectric properties.

Table 3 and Fig. 2 show the results of a calorimetric study of the heat capacities of synthesized ternary lutetium tellurites.

Equations for the temperature dependence of the heat capacities of compounds by mathematical processing of experimental data were derived. The equation coefficients are given in Table 4.

Since the technical capabilities of the calorimeter do not allow calculating the standard entropies of compounds from experimental data on heat capacities, they are estimated using the ion increment method according to the scheme [19]:

$$S^0\,(298.15)\ LuMeFeTeO_6 = S'\,(298.15)\ Lu^{\ 3+} + S'\,(298.15)\ Me^{\ 2+} + S'\,(298.15)\ Fe^{\ 3+} + S'\,(298.15)\ Te^{\ 4+} + 6S'\,(298.15)\ O^{\ 2-}, \qquad (2)$$

where S' (298.15) - entropy increment of the ion, at 298.15 K; $Me^{\ 2+}$ ($Sr^{\ 2+}$, $Ba^{\ 2+}$).

The values of S' (298.15) $Lu^{3+}$, $Sr^{2+}$, $Ba^{2+}$, $Fe^{3+}$, $Te^{4+}$, $O^{2-}$ required for the calculation are borrowed from [19].

Based on the experimental data on $C_p^0(T)$ and the calculated values of $S^0(298.15)$, the temperature dependences of the thermodynamic functions were calculated: $C_p^0(T)$, $S^0(T)$, $H^0(T)$ - $H^0(298.15)$ and $\Phi^{xx}(T)$ (Table 5). The thermodynamic functions $H^0(T)$ - $H^0(298.15)$, $S^0(T)$ and $\Phi^{xx}(T)$ were calculated using the following formulas [20]:

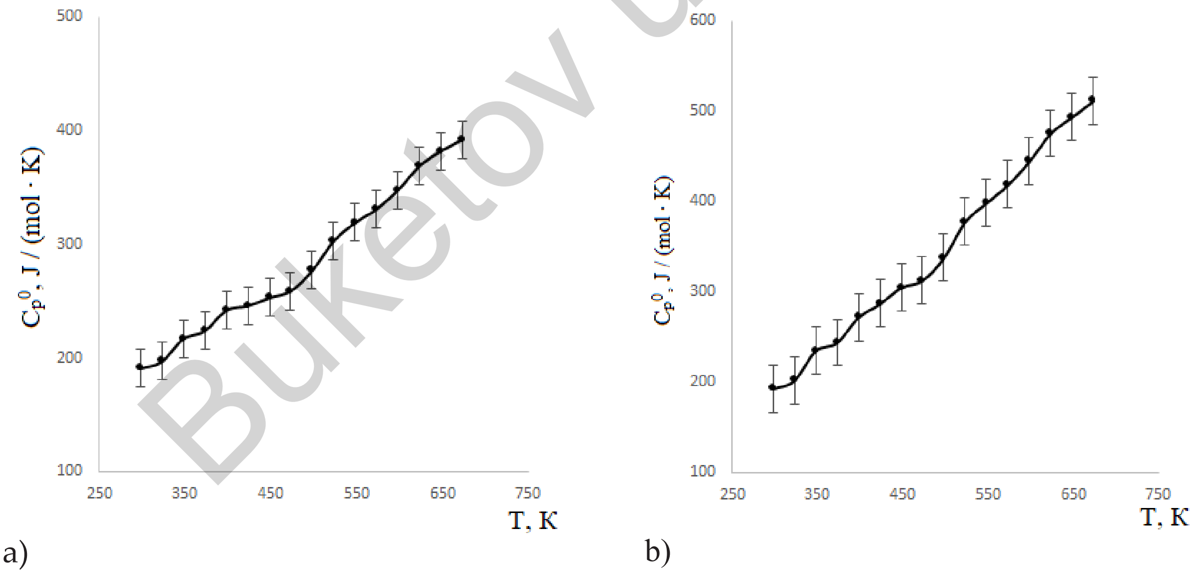
$$H^0(T) - H^0(298.15) = \int_{298.15}^{T} C_p^0 dT, \qquad (3)$$

Table 2. Types of syngony and unit cell parameters of triple lutetium tellurites.

| Compound | Type of syngony | Lattice parameters, Å | | $V^0_{unit\ cell}$, Å$^3$ | Z | Density, g cm $^{-3}$ | |
|---|---|---|---|---|---|---|---|
| | | a | c | | | radiog. | pycnom. |
| $LuSrFeTeO_6$ | tetragonal | 12.021 ± 0.02 | 6.534 ± 0.02 | 944.19 ± 0.02 | 3 | 2.86 | 2.84 ± 0.02 |
| $LuBaFeTeO_6$ | tetragonal | 10.011 ± 0.03 | 10.461 ± 0.03 | 1048.40 ± 0.02 | 4 | 3.99 | 3.97 ± 0.02 |

Table 3. Experimental values of the heat capacities of triple lutetium tellurites.

| T, K | $C_p \pm \bar{\delta}$, J g$^{-1}$ K$^{-1}$ | $C_p^0 \pm \overset{0}{\Delta}$, J mol$^{-1}$ K$^{-1}$ | T, K | $C_p \pm \bar{\delta}$, J g$^{-1}$ K$^{-1}$ | $C_p^0 \pm \overset{0}{\Delta}$, J mol$^{-1}$ K$^{-1}$ |
|---|---|---|---|---|---|
| $LuSrFeTeO_6$ | | | | | |
| 298.15 | 0.3525 ± 0.0360 | 191 ± 10 | 498 | 0.5107 ± 0.0273 | 277 ± 10 |
| 323 | 0.3642 ± 0.0061 | 197 ± 11 | 523 | 0.5600 ± 0.0231 | 303 ± 11 |
| 348 | 0.3997 ± 0.0147 | 217 ± 11 | 548 | 0.5881 ± 0.0262 | 319 ± 13 |
| 373 | 0.4140 ± 0.0155 | 224 ± 9 | 573 | 0.6107 ± 0.0259 | 331 ± 15 |
| 398 | 0.4470 ± 0.0276 | 242 ± 8 | 598 | 0.6415 ± 0.0213 | 348 ± 13 |
| 423 | 0.4545 ± 0.0285 | 246 ± 8 | 623 | 0.6813 ± 0.0214 | 369 ± 11 |
| 448 | 0.4668 ± 0.0322 | 253 ± 8 | 648 | 0.7066 ± 0.0203 | 382 ± 8 |
| 473 | 0.4785 ± 0.0296 | 259 ± 10 | 673 | 0.7224 ± 0.0229 | 392 ± 11 |
| $LuBaFeTeO_6$ | | | | | |
| 298.15 | 0.3229 ± 0.0360 | 193 ± 10 | 498 | 0.5714 ± 0.0064 | 338 ± 10 |
| 323 | 0.3418 ± 0.0061 | 202 ± 11 | 523 | 0.6391 ± 0.0065 | 378 ± 11 |
| 348 | 0.3981 ± 0.0058 | 235 ± 11 | 548 | 0.6739 ± 0.0180 | 399 ± 13 |
| 373 | 0.4125 ± 0.0085 | 244 ± 9 | 573 | 0.7087 ± 0.0220 | 419 ± 15 |
| 398 | 0.4601 ± 0.0081 | 272 ± 8 | 598 | 0.7520 ± 0.0216 | 445 ± 13 |
| 423 | 0.4849 ± 0.0076 | 287 ± 8 | 623 | 0.8042 ± 0.0247 | 476 ± 11 |
| 448 | 0.5147 ± 0.0075 | 305 ± 8 | 648 | 0.8345 ± 0.0220 | 494 ± 8 |
| 473 | 0.5295 ±0.0070 | 313 ± 10 | 673 | 0.8659 ± 0.0169 | 512 ± 11 |



a) b)

Fig. 2. Dependences of the heat capacities of tellurites on temperature: (a) $LuSrFeTeO_6$, (b) $LuBaFeTeO_6$.

Table 4. Equations for the temperature dependence of the heat capacities of triple lutetium tellurites.

| Compound | Equation coefficients $C_p^0 = a + bT + cT^{-2}$, J mol$^{-1}$ K$^{-1}$) | | | ΔT, K |
|---|---|---|---|---|
| | a | b × $10^{-3}$ | c × $10^5$ | |
| $LuSrFeTeO_6$ | - (127.59 ± 3.05) | 743.21 ± 2.24 | 86.03 ± 2.21 | 298 - 673 |
| $LuBaFeTeO_6$ | - (251.99 ± 3.11) | 1454.2 ± 2.31 | 10.33 ± 2.27 | 298 - 673 |

$$S^0(T) = S^0(298.15) + \int_{298.15}^{T} \frac{C_p}{T} dT, \qquad (4)$$

$$\Phi^{xx}(T) = S^0(T) - [H^0(T) - H^0(298.15)]/T \qquad (5)$$

For all values of heat capacity and enthalpy across the entire temperature range, the average random components of the error are estimated. Additionally, the error estimate includes the accuracy of the entropy calculation (± 3 %) for the values of entropy and reduced thermodynamic potential.

Table 5. Thermodynamic functions of tellurites in the range 298.15 - 673 K.

| T, K | $C_p^0(T) \pm \overset{0}{\Delta}$, J mol$^{-1}$ K$^{-1}$ | $S^0(T) \pm \overset{0}{\Delta}$, J mol$^{-1}$ K$^{-1}$ | $H^0(T) - H^0(298.15) \pm \overset{0}{\Delta}$, J mol$^{-1}$ | $\Phi^{xx}(T) \pm \overset{0}{\Delta}$, J mol$^{-1}$ K$^{-1}$ |
|---|---|---|---|---|
| $LuSrFeTeO_6$ | | | | |
| 298.15 | 191 ± 9 | 220 ± 8 | - | 220 ± 16 |
| 323 | 195 ± 10 | 235 ± 18 | 4788 ± 223 | 221 ± 16 |
| 348 | 202 ± 11 | 250 ± 19 | 9743 ± 453 | 222 ± 16 |
| 373 | 211 ± 11 | 265 ± 20 | 14903 ± 693 | 225 ± 16 |
| 398 | 222 ± 10 | 279 ± 21 | 20317 ± 945 | 228 ± 17 |
| 423 | 235 ± 12 | 292 ± 22 | 26025 ± 1210 | 231 ± 17 |
| 448 | 248 ± 11 | 306 ± 24 | 32054 ± 1491 | 235 ± 18 |
| 473 | 262 ± 13 | 320 ± 25 | 38429 ± 1787 | 239 ± 19 |
| 498 | 277 ± 13 | 334 ± 26 | 45166 ± 2101 | 243 ± 19 |
| 523 | 292 ± 14 | 348 ± 27 | 52283 ± 2432 | 248 ± 19 |
| 548 | 308 ± 14 | 362 ± 28 | 59791 ± 2781 | 253 ± 19 |
| 573 | 324 ± 14 | 376 ± 29 | 67699 ± 3149 | 258 ± 20 |
| 598 | 341 ± 15 | 390 ± 30 | 76017 ± 3536 | 263 ± 20 |
| 623 | 358 ± 15 | 405 ± 30 | 84752 ± 3942 | 269 ± 21 |
| 648 | 375 ± 16 | 419 ± 31 | 93909 ± 4368 | 274 ± 21 |
| 673 | 392 ± 17 | 434 ± 31 | 103493 ± 4814 | 280 ± 22 |
| $LuBaFeTeO_6$ | | | | |
| 298.15 | 193 ± 9 | 230 ± 9 | - | 230 ± 17 |
| 323 | 233 ± 9 | 247 ± 18 | 5311 ± 247 | 231 ± 17 |
| 348 | 266 ± 10 | 266 ± 18 | 11565 ± 538 | 232 ± 17 |
| 373 | 294 ± 11 | 285 ± 18 | 18578 ± 864 | 235 ± 18 |
| 398 | 318 ± 11 | 305 ± 19 | 26235 ± 1220 | 239 ± 18 |
| 423 | 339 ± 11 | 325 ± 19 | 34447 ± 1602 | 244 ± 19 |
| 448 | 357 ± 12 | 345 ± 21 | 43144 ± 2007 | 249 ± 20 |
| 473 | 373 ± 12 | 365 ± 21 | 52274 ± 2431 | 254 ± 20 |
| 498 | 388 ± 13 | 384 ± 22 | 61792 ± 2874 | 260 ± 21 |
| 523 | 402 ± 14 | 404 ± 22 | 71663 ± 3333 | 267 ± 21 |
| 548 | 414 ± 14 | 424 ± 22 | 81859 ± 3807 | 273 ± 21 |
| 573 | 426 ± 15 | 442 ± 23 | 92357 ± 4296 | 280 ± 21 |
| 598 | 437 ± 15 | 460 ± 24 | 103136 ± 4797 | 287 ± 22 |
| 623 | 447 ± 16 | 478 ± 25 | 114180 ± 5310 | 295 ± 23 |
| 648 | 457 ± 17 | 496 ± 25 | 125475 ± 5836 | 302 ± 24 |
| 673 | 466 ± 17 | 513 ± 26 | 137009 ± 6372 | 310 ± 24 |

## CONCLUSIONS

New ternary lutetium tellurites of the composition $LuMeFeTeO_6$ (Me - Sr, Ba) have been synthesized for the first time. X - ray characteristics (types of syngony, unit cell parameters, X - ray and pycnometric densities) are obtained using an Empyrean powder diffractometer and specialized programs Data Collector version 7.7h and X’Pert HighScore Plus using the Crystallography Open Database and PDF - 2 databases. It has been established that tellurites crystallize in the tetragonal system in the distorted perovskite structural type. Therefore, it can be assumed that these compounds may have semiconductor and ferroelectric properties.

For the first time using the method of dynamic calorimetry in the temperature range 298.15 - 673 K, the isobaric heat capacities of tellurites are studied, based on which the equations for the dependence $C_p(T)$ are derived. A fundamental constant is determined - the standard heat capacity of new tellurites. The temperature dependences of the thermodynamic functions $S^0(T)$, $H^0(T) - H^0$ (298.15), $\Phi^{xx}(T)$ are calculated.

The study results are important for inorganic and physical chemistry of oxide materials, as well as inorganic materials science. They can also be utilized for inclusion in reference books and thermodynamic data banks.

The data obtained serve as the basis for further research on the electrophysics of the synthesized new tellurites.

## REFERENCES

1. J.Zhu, H.Li, L.Zhong, P. Xiao, Perovskite oxides: preparation, characterizations, and applications in heterogeneous catalysis, ACS Catalysis, 4, 9, 2014, 2917-2940.
2. X. Li, H. Zhao, J. Liang, Y. Luo, G. Chen, X. Shi, S. Lu, Sh. Gao, J. Hu, Q. Liu, X. Sun, A-site perovskite oxides: an emerging functional material for electrocatalysis and photocatalysis, J. Mater. Chem. A, 9, 11, 2021, 6650-6670.
3. A.A. Washman, K.I. Petrov, Fundamental inorganic compounds of lithium., Energoatomizdat: Moscow, 1996, (in Russian).
4. B.K. Kasenov, N.S. Bekturganov, B.T. Ermagambet, Sh.B. Kasenova, Zh.I. Sagintaeva, M.A. Isabaeva, Manganites, chromites, ferrites of rare earth, alkali and alkaline earth metals, Litera LLP: Karaganda, Kazakhstan, 2016, (in Russian).
5. H.E. Lee, H. Jo, M. H. Lee, K.M. Ok, Unique synthesis, structure determination, and optical properties of seven new layered rare earth tellurite nitrates, $RE(TeO_3)(NO_3)$ (RE = La, Nd, Eu, Gd, Dy, Er, and Y), J. Alloys and Compounds, 851, 2021, 156855.
6. M. Wen., H. Wu, C. Hu, Zh. Yang, Sh. Pan, Experiment and First-Principles Calculations of $A_2Mg_2TeB_2O_{10}$ (A = Pb, Ba): Influences of the Cosubstitution on the Structure Transformation and Optical Properties, Inorg. Chem., 58, 2019.
7. W. Lu, Z. Gao, Q. Wu, X.Tian, Y. Sun, Ya. Liu, X. Tao, Tailored fabrication of a prospective acousto-optic crystal $TiTe_3O_8$ endowed with high performance, J. Mater. Chem. C, 6, 10, 2018, 2443-2451.
8. K.M. Ok, E.O. Chi, P.S. Halasyamani, Bulk characterization methods for non-centrosymmetric materials: second-harmonic generation, piezoelectricity, pyroelectricity, and ferroelectricity, Chem. Soc. Rev., 35, 8, 2006, 710.
9. K. Rustembekov, A. Toibek, M. Stoev, G. Mukusheva, T. Sadykov, Synthesis and properties of $NdMe^{II}TeO_{4.5}$ ($Me^{II}$ - Ca, Ba) tellurites, J. Chem. Technol. Metall., 59, 1, 2024, 157-164.
10. K.T. Rustembekov, B.K. Kasenov, A.Zh. Bekturganova, M.S. Kasymova, Thermodynamic and electrophysical properties of $La_2SrNiTeO_7$, Russ. J. Phys. Chem. A, 93, 9, 2019, 1665-1669.
11. Specification and Operating Instructions of IT-C-400, Aktobe. Aktobe Plant “Etalon”. 1986, 48, (in Russian). Available online: https://nd-gsi.ru/grsi/060xx/06000-77.pdf (accessed on 13 March 2024).
12. E.S. Platunov, S.E. Buravoy, V.V. Kurepin, Thermophysical measurements and instruments, Mechanical Engineering: Leningrad, 1986, (in Russian).
13. K.T. Rustembekov, M.S. Kasymova, D.A. Kaikenov, V.N. Fomin, S.K. Aldabergenova, A.A. Toibek, Calobrimetry of new double dysprosium tellurite, Bulletin of the Karaganda University, “Chemistry” series, 93, 1, 2019, 60-65.
14. R.A. Robie, B.S. Hewingway, I.R. Fisher,

Thermodynamic Properties of Minerals and Ralated Substances at 298.15 K and ($10^5$ Pa) Pressure and at Higher Temperatures, United States Government Printing Office: Washington, 1978.

15. V.Yu. Bodryakov, A.A. Bykov, Characteristics of the Volumetric Thermal Expansion Coefficient and Specific Heat of Corundum, Glass Ceramics, 2, 2015, 30, (in Russian).
16. Crystallography Open Database, http://www.crystallography.net/cod/result.php
17. A. Welles, Structural inorganic chemistry, 2, Mir: Moscow, 1987, (in Russian).
18. K. Saito, S. Hayakawa, F. Taxi, Chemistry and Periodic System / ed. K. Saito; per. from Japanese Mir: Moscow, 1982, 320, (in Russian).
19. V.N. Kumok In: Direct and inverse problems of chemical thermodynamics. Science: Novosibirsk, 1987, p.108, (in Russian).
20. K.T. Rustembekov, A.Zh. Bekturganova, X-ray diffraction and thermodynamic characteristics for tellurite of composition $Li_2CeTeO_5$, Russ. J. Phys. Chem. A, 91, 4, 2017, 622-626.