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# X-ray and thermochemical investigations on SrUTeO<sub>6</sub> and SrUTe<sub>2</sub>O<sub>8</sub>

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## Abstract

Solid state reactions of  $SrUO_4$  and  $TeO_2$  in 1:1 and 1:2 molar ratio led to the formation of two new quaternary compounds  $SrUTeO_6$ and  $SrUTe_2O_8$ . The compounds were characterised by X-ray and thermal methods. X-ray powder diffraction data of both the compounds were indexed on the monoclinic system. The standard Gibbs free energy of formation ( $\Delta_f G^\circ$ , *T*) data of  $SrUTeO_6(s)$  and  $SrUTe_2O_8(s)$ were obtained by the vapour pressure measurement of  $TeO_2(g)$  over these systems by employing the Knudsen effusion mass loss (KEML) technique and could be represented by the relation:

 $\Delta_{f}G^{\circ}$ SrUTeO<sub>6</sub>(s) = (-2180.7 + 0.4263T (K))±30 kJ mol<sup>-1</sup> [1080-1162 K]

 $\Delta_{\rm f} G^{\circ} {\rm SrUTe}_2 {\rm O}_8({\rm s}) = (-2502.6 + 0.5816T \, ({\rm K})) \pm 30 \, {\rm kJ \, mol}^{-1} \, [955 - 1041 \, {\rm K}]$ 

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## 1. Introduction

Tellurium is one of the highly corrosive fission products that can interact with fissile elements and other fission products of the oxide fuels within the reactor forming binary and ternary oxides [1]. Barium and strontium are the alkaline earth fission products which form insoluble oxide phases in the fuel matrix. Tellurium can also react with these fission products forming ternary and quaternary compounds. A number of uranates of strontium and tellurium are reported in the literature [2-6]. In the quarternary system, preparation of the double tellurates of actinides and alkaline earth metals with uranium(VI) corresponding to the general formula  $M_3UO_2(TeO_3)_4$  and  $M_2U(TeO_3)_5$ , where M=Ba or Ca have been reported in the literature [7]. However, there are no such data available in the literature on Sr-U-Te-O quaternary systems. In continuation of our earlier studies on the ternary systems of tellurium-bearing compounds [8-10], we report the X-ray, thermal and Gibbs free energy of formation of the two new phases  $SrUTeO_6(s)$  and  $SrUTe_2O_8(s)$  in this paper.

#### 2. Experimental

## 2.1. Preparation and characterisation of the compounds

SrUTeO<sub>6</sub>(s) and SrUTe<sub>2</sub>O<sub>8</sub>(s) were prepared by heating a mixture of SrUO<sub>4</sub>(s) and TeO<sub>2</sub>(s) in a 1:1 and 1:2 molar ratio in argon atmosphere at 1075 K. Strontium uranate SrUO<sub>4</sub>(s), was prepared by heating a mixture of SrCO<sub>3</sub>(s) and U<sub>3</sub>O<sub>8</sub>(s) in a 3:1 molar ratio in a furnace in air atmosphere at 1225 K. The products were removed intermittently, ground and reheated to obtain pure phases of the compounds. The formation of the compound was confirmed from their X-ray diffraction patterns recorded on a Diano X-ray diffractometer using graphite monochromatized Cu K $\alpha_1$  radiation ( $\lambda$ =0.15406 nm).

## 2.2. TG and DTA measurements

The thermal behaviour of  $SrUTeO_6(s)$  and  $SrUTe_2O_8(s)$  was studied by recording their TG and DTA patterns simultaneously in the ULVAC thermal analyser. The experiments were carried out in air in alumina cups at a heating rate of 10 K/min up to 1473 K. Preheated sintered alumina was used as the reference material in DTA experiments.

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### 2.3. Vapour pressure measurements

The mass loss measurements were carried out in a Cahn vacuum microbalance by the Knudsen effusion mass loss (KEML) technique. Boron nitride cell with an orifice diameter of  $\approx 1.0$  mm at the center of the lid was used as the Knudsen cell. Detailed experimental set-up and the Clausing factor calibration for the Knudsen cell have been described in our earlier studies [11].

# 3. Results and discussion

## 3.1. Characterisation by XRD

The X-ray diffraction patterns of  $SrUTeO_6(s)$  and  $SrUTe_2O_8(s)$  formed by reacting  $SrUO_4(s)$  and  $TeO_2(s)$  in the ratio of 1:1 and 1:2 in argon at 1023 K, were different from those of the reported phases in Sr-U-O, Sr-Te-O and U-Te-O systems [12]. Alternatively, these compounds were also obtained by heating mixtures of SrO(s) and  $UTeO_5(s)$  and  $SrTeO_3(s)$  and  $UTeO_5(s)$  in the respective molar ratios under similar conditions. The X-ray powder diffraction data of  $SrUTeO_6(s)$  and  $SrUTe_2O_8(s)$  were indexed on the monoclinic system. The refined cell parameters and the indexed diffraction data of both the compounds are given in Tables 1 and 2, respectively.

# 3.2. Thermal behaviour in air

The decomposition of  $SrUTe_2O_8(s)$  takes place in a single step in the temperature range of 975–1400 K forming  $SrUO_4(s)$ , as identified from its XRD pattern. XRD analysis of the volatile product of  $SrUTe_2O_8(s)$ 

Table 2

X-ray diffraction data of SrUTe <sub>2</sub> O <sub>8</sub> ; $a = 1.3038(3)$ nm, $b = 0.5434(3)$ r	nm
$c = 1.2516(3) \text{ nm}, \beta = 93.31^{\circ}(3), (\lambda = 0.15406 \text{ nm})$	

h k l	$d_{\rm obs}$ (nm)	$d_{\rm cal}$ (nm)	$I/I_0$
200	0.6487	0.6508	34
-1 0 2	0.5746	0.5763	18
-202	0.4639	0.4642	26
203	0.3423	0.3420	28
013	0.3303	0.3306	96
400	0.3253	0.3254	100
-204	0.2882	0.2882	43
4 0 2	0.2818	0.2820	51
014	0.2708	0.2708	20
114	0.2627	0.2625	12
510	0.2346	0.2348	09
$-2\ 2\ 2$		0.2345	
321	0.2251	0.2252	10
-223	0.2169	0.2169	09
-206	0.2018	0.2018	70
600		0.2018	
611	0.1972	0.1973	18
504	0.1943	0.1945	12
016		0.1945	
-514	0.1924	0.1925	12
-521	0.1869	0.1870	09
-207	0.1747	0.1747	09
-712	0.1717	0.1718	36
620	0.1695	0.1695	35
$-1\ 1\ 7$		0.1694	
-622	0.1655	0.1655	09
-713		0.1653	
026		0.1653	

showed condensation of  $\text{TeO}_2(s)$  at the cooler part of the reaction tube, confirming the volatilization of  $\text{TeO}_2(s)$ . The thermal decomposition of  $\text{SrUTe}_2\text{O}_8(s)$  in air could be represented by Eq. (1)

$$SrUTe_2O_8(s) \rightarrow SrUO_4(s) + 2TeO_2(g)$$
(1)

Table 1

X-ray diffraction data of SrUTeO<sub>6</sub>; a = 1.3579(3) nm, b = 0.9766(2) nm, c = 0.9903(2) nm,  $\beta = 107.16^{\circ}(2)$ , ( $\lambda = 0.15406$  nm)

h k l	$d_{\rm obs}$ (nm)	$d_{\rm cal}$ (nm)	$I/I_0$	h k l	$d_{\rm obs}$ (nm)	$d_{\rm cal}$ (nm)	$I/I_0$
101	0.6758	0.6752	33	401	0.2823	0.2822	22
200	0.6482	0.6486	17	-123	0.2731	0.2732	20
201	0.4737	0.4736	23	-104	0.2457	0.2458	13
021	0.4338	0.4339	16	-114	0.2387	0.2384	16
-312	0.3539	0.3541	28	042	0.2168	0.2169	09
-122	0.3470	0.3472	48	-342	0.2055	0.2054	24
221	0.3399	0.3400	40	124	0.2018	0.2016	26
022		0.3397					
-222	0.3313	0.3313	40	043	0.1931	0.1931	19
				150		0.1931	
030	0.3255	0.3255	100	522	0.1879	0.1878	16
400		0.3243					
212	0.3190	0.3191	40	251	0.1806	0.1806	14
				052		0.1805	
-402	0.3141	0.3143	25	612	0.1750	0.1749	14
-131	0.3060	0.3062	26	351	0.1713	0.1712	26
013	0.3000	0.3000	44	-724	0.1628	0.1629	14
-322		0.2999		060		0.1628	
230	0.2908	0.2909	40				

The plot of alpha ( $\alpha$ ), the fractional weight loss ( $\alpha = (w_i - w_T)/(w_i - w_f)$ , where  $w_i$ ,  $w_f$  and  $w_T$  are the mass at initial, final and at temperature *T*) versus temperature for the compound SrUTe<sub>2</sub>O<sub>8</sub>(s) and pure TeO<sub>2</sub>(s) is shown in Fig. 1. The  $\alpha$  plots of SrUTe<sub>2</sub>O<sub>8</sub>(s) and TeO<sub>2</sub>(s) are similar indicating that the kinetics of decomposition of the compound is controlled by the evaporation of TeO<sub>2</sub>(g).

The DTA curve of  $SrUTe_2O_8(s)$  showed an endothermic peak at 1213 K due to the melting of the compound before decomposition, as shown in Fig. 1. In the case of  $SrUTeO_6(s)$ , the decomposition is accompanied by melting of the compound at 1208 K. The DTA showed a broad endothermic peak due to its decomposition occurring over a wide range of temperatures. The final product of decomposition of  $SrUTeO_6(s)$  in air was also identified as  $SrUO_4(s)$ .

## 3.3. Vapour pressure measurements

#### 3.3.1. SrUTeO<sub>6</sub>

The vapour pressure measurements by KEML technique were first carried out for SrUTeO<sub>6</sub>(s), in order to obtain  $\Delta_{\rm f}G^{\circ}$  (SrUTeO<sub>6</sub>, s, T), since this value has been used to calculate the Gibbs free energy formation of SrUTe<sub>2</sub>O<sub>8</sub>(s) in the subsequent experiments.

Under the conditions of measurements of partial pressure of the evolved gases, the thermal decomposition of  $SrUTeO_6$  in vacuum is represented by Eq. (2)

$$SrUTeO_6(s) \rightarrow SrUO_{3.597}(s) + TeO_2(g) + 0.2015 O_2(g) [1080-1162 K]$$
 (2)

The formation of nonstoichiometric  $SrUO_{3.597}(s)$ , a dark green product, in vacuum was identified from its XRD pattern. Takahashi et al. [13] have prepared nonstoich-



Fig. 1. The plot of  $\alpha$  versus temperature for (A) SrUTe<sub>2</sub>O<sub>8</sub>, (B) TeO<sub>2</sub> and (C) DTA of SrUTe<sub>2</sub>O<sub>8</sub> in air.

iometric compounds in Sr–U–O system in sealed vacuum ampoules and have reported the structural analysis of the stable phase SrUO<sub>3.597</sub>(s). The XRD data of SrUO<sub>3.597</sub>(s) obtained in our studies (Eq. (2)), could be indexed on the hexagonal system with cell parameters a=3.996(4) and c=18.506(6) Å. These values are in close agreement with the values reported by Takahashi et al. [13] and Fujino et al. [14]. The thermal stability of various nonstoichiometric alkaline earth monouranates in different atmospheres up to 1273 K, have been reported by Tagawa et al. [15]. They have identified the formation of various nonstoichiometric strontium uranates such as SrUO<sub>3.563</sub>(s), SrUO<sub>3.997</sub>(s), SrUO<sub>3.673</sub>(s) and SrUO<sub>3.175</sub>(s) in different atmospheres on heating SrUO<sub>4</sub>(s) in vacuum, air, carbon dioxide, and hydrogen, respectively.

The equilibrium vapour pressures of  $\text{TeO}_2(g)$  and 0.2015  $O_2(g)$  were derived in the temperature range of 1080–1162 K over a mixture of  $\text{SrUTeO}_6(s)$  and  $\text{SrUO}_{3.597}(s)$ . The total mass loss due to  $\text{TeO}_2(g)$  and  $O_2(g)$  was apportioned in terms of their molar masses and could be given as:

$$dw/dt = (dw_1/dt) + (dw_2/dt)$$
(3)

where dw/dt is the experimentally measured combined rate of mass loss of TeO<sub>2</sub>(g) and O<sub>2</sub>(g),  $dw_1/dt$  and  $dw_2/dt$  are the individual rate of mass losses of TeO<sub>2</sub>(g) and O<sub>2</sub>(g), respectively. A similar apportionation procedure has been followed in our earlier studies on Ni<sub>3</sub>TeO<sub>6</sub> compound in the Ni–Te–O system and Cr<sub>2</sub>TeO<sub>6</sub>(s) and Fe<sub>2</sub>TeO<sub>6</sub>(s) in the Cr/Fe–Te–O systems [9,16]. The mathematical derivation for the rate of mass loss is, using Eq. (3),

$$dw_1/dt = [(dw/dt).(792.10/824.1)]$$
  
= (dw/dt).(0.9612) (4)

By substituting the value of  $dw_1/dt$  in Eq. (3),  $dw_2/dt$  can be calculated. Thus by inserting the individual mass loss of  $dw_1/dt$  and  $dw_2/dt$  in the rate of mass loss Eq. (5)

$$p (Pa) = [(dw/dt).(1/kA).(2.28 \times 10^{-3}).\sqrt{T/M}]$$
(5)

where *p* is the partial pressures of the evolved gas, *k* is the Clausing factor, *A* is the area of the orifice diameter, *T* is the temperature and *M* is the molecular weight of the evolved gaseous species, the individual partial pressures contributed by TeO<sub>2</sub>(g) and O<sub>2</sub>(g) were determined and are given in Table 3. The corresponding least squares fit of log *p* of TeO<sub>2</sub>(g) with 1/T is shown in Fig. 2 and could be represented by the relation:

$$\log p_{\text{TeO}_2(g)} \text{ (kPa)} \pm 0.03 = -8119.9/T \text{ (K)} + 5.0535 [1080-1162 \text{ K}]$$
(6)

The least squares fit of log p of  $O_2(g)$  versus 1/T can be given as:

Table 3 Gibbs free energy of formation of  $SrUTeO_6(s)$  at different temperatures

Temperature (K)	$p_{\text{TeO}_{2}(g)}$ (kPa)×10 <sup>-3</sup>	$p^{\circ}_{\text{TeO}_2(g)}$ (kPa)×10 <sup>-3</sup>	$p_{o_{2}(g)}$ (kPa)×10 <sup>-4</sup>	$\Delta_{\rm f} G^{\circ} { m SrUTeO}_{\rm 6}({ m s})$ (kJ mol <sup>-1</sup> )
1080	3.60	86.1	1.5	-1720.3
1092	4.30	111.9	1.8	-1715.2
1099	4.70	130.1	1.9	-1712.2
1114	5.60	178.4	2.3	-1705.8
1121	6.01	206.1	2.4	-1702.8
1129	6.62	242.6	2.7	-1699.4
1140	8.70	302.4	3.2	-1694.7
1150	9.50	368.1	3.6	-1690.5
1162	11.0	463.9	4.0	-1685.3

$$\log p_{O_2(g)}$$
 (kPa) $\pm 0.01 = -6872/T$ 

$$+ 2.5343 [1080 - 1162 \text{ K}]$$
 (7)

The standard Gibbs free energy of formation of  $SrUTeO_6(s)$  is represented by the relation:

$$\Delta_{\rm f} G^{\circ} {\rm SrUTeO}_6({\rm s}) = \Delta_{\rm f} G^{\circ} {\rm SrUO}_{3.597}({\rm s}) + \Delta_{\rm f} G^{\circ} {\rm TeO}_2({\rm l})$$
$$+ 0.2015 RT \ln p_{\rm O_2(g)}$$
$$+ RT \ln (p_{\rm TeO_2}/p^{\circ}_{\rm TeO_2}) \qquad (8)$$

where  $p_{\text{TeO}_2}$  is the measured vapour pressure data (Eq. (6)),  $p^{\circ}_{\text{TeO}_2}$  is the partial pressure of  $\text{TeO}_2(g)$  over  $\text{TeO}_2(l)$  and the vapour pressure data are taken from the literature [17,18].

The experimental  $\Delta_{\rm f}G^{\circ}({\rm SrUO}_{3.597}, {\rm s}, T)$  values are not reported in the literature. So the estimation of  $\Delta_{\rm f}G^{\circ}({\rm SrUO}_{3.597}, {\rm s}, T)$  was carried out using the method suggested by Lindemer et al. [19]. In this method, either  $\Delta_{\rm f}H^{\circ}_{\rm m}(298.15 \text{ K})$  or  $\Delta_{\rm f}G^{\circ}_{\rm m}(T)$  value of at least one of the ternary compounds in the required system should be experimentally known. Error involved in this type of



Fig. 2. Temperature dependence of the vapour pressure of  $TeO_2(g)$  over (A) SrUTeO<sub>6</sub>(s) and SrUO<sub>3.597</sub>(s), and (B) SrUTe<sub>2</sub>O<sub>8</sub>(s) and SrUTeO<sub>6</sub>(s).

estimation is within  $\pm 20$  kJ mol<sup>-1</sup> [19]. To evaluate,  $\Delta_{\rm f} G^{\circ}_{\rm m}(T)$  values for unknown compounds in the Sr–U–O system, maximum possible chemical reactions should be written, in terms of the ternary oxides. The chemical reactions considered are:

$$SrUO_4(s) + 0.052 U_3O_8(s) = SrUO_{3.948}(s) + 0.156 UO_3(s)$$
(9)

$$SrUO_{3.948}(s) + 0.171 U_{3}O_{8}(s) = SrUO_{3.777}(s) + 0.513 UO_{3}(s)$$
(10)

$$SrUO_{3.777}(s) + 0.0546 U_{3}O_{8}(s) + 0.0418 U_{4}O_{9}(s)$$
  
= SrUO\_{3.597}(s) + 0.331 UO\_{3}(s) (11)

$$SrO(s) + 0.2776 U_3O_8(s) + 0.0418 U_4O_9(s) = SrUO_{3.597}(s)$$
(12)

$$SrO(s) + 0.052 U_3O_8(s) + 0.844 UO_3(s) = SrUO_{3.948}(s)$$
(13)

$$SrO(s) + 0.223 U_3O_8(s) + 0.331 UO_3(s) = SrUO_{3.777}(s)$$
(14)

$$SrUO_{3.948}(s) + SrUO_{3.597}(s) + 0.0072 U_3O_8(s)$$
  
= 2 SrUO<sub>3.777</sub>(s) + 0.0054 U<sub>4</sub>O<sub>9</sub>(s) (15)

For any chemical reaction, one can write:

$$\Delta_{\rm r}G^{\circ}_{\ \rm m}(T) + c = 0 \tag{16}$$

where *c* is a constant and can be positive (reaction favorable), negative (reaction not favorable) or zero (equilibrium). For each of these chemical Eqs. (9)–(15), one can yield an expression of the type given by Eq. (16). By substituting known  $\Delta_f G^{\circ}_m(T)$  values for SrUO<sub>4</sub>(s), U<sub>3</sub>O<sub>8</sub>(s), U<sub>4</sub>O<sub>9</sub>(s) and UO<sub>3</sub>(s) from the literature [20,21] and T = 900 K in each expression the following equations are obtained:

$$G(\text{SrUO}_{3,948}) + 1659775 + a = 0 \tag{17}$$

$$G(\text{SrUO}_{3.777}) - G(\text{SrUO}_{3.948}) - 675 + b = 0$$
(18)

$$G(\text{SrUO}_{3.597}) - G(\text{SrUO}_{3.777}) - 6252 + c = 0$$
(19)

$$G(\text{SrUO}_{3.597}) + 1490558 + d = 0 \tag{20}$$

$$G(\text{SrUO}_{3.948}) + 1497485 + e = 0 \tag{21}$$

$$G(\text{SrUO}_{3,777}) + 1496809 + f = 0 \tag{22}$$

$$2 G(\text{SrUO}_{3.777}) - G(\text{SrUO}_{3.948}) - G(\text{SrUO}_{3.597}) + 751 + g$$
  
= 0 (23)

where  $G(\text{SrUO}_{3.948})$ ,  $G(\text{SrUO}_{3.777})$  and  $G(\text{SrUO}_{3.597})$  represent the  $\Delta_{f}G^{\circ}_{m}(900 \text{ K})$  for  $\text{SrUO}_{3.948}(s)$ ,  $\text{SrUO}_{3.777}(s)$  and  $\text{SrUO}_{3.597}(s)$ , respectively. By eliminating the unknown Gibbs energy of formation values algebraically from the above equalities one gets:

$$a + b + 2c - d + e - f + g = -157472$$
(24)

This relationship is very useful because, it puts a constraint on the permissible values of *a*, *b*, *c*, *d*, *e*, *f* and *g*. The number of unknowns exceeds the number of equations. Iteration method with an initial gauss value is used to solve the above equation sets. The resulting  $\Delta_{\rm f}G^{\circ}(T)$  values for the SrUO<sub>3.948</sub>(s), SrUO<sub>3.777</sub>(s) and SrUO<sub>3.597</sub>(s) compounds are -1659, -1634.0 and -1606.5 kJ mol<sup>-1</sup> respectively, while the values of *a*, *b*, *c*, *d*, *e*, *f* and *g* are -0.8, -24.32, -21.2, 116, 161.6, 137.2, 1.7 kJ, respectively. This method of estimation has been repeated for T = 1000 K and 1100 K.  $\Delta_{\rm f}G^{\circ}(\text{SrUO}_{3.597}, \text{ s}, T)$  value is calculated as -1572.0 kJ mol<sup>-1</sup> at 1000 K and -1537.9 kJ mol<sup>-1</sup> at 1100 K. Least squares analysis of  $\Delta_{\rm f}G^{\circ}(\text{SrUO}_{3.597}, \text{ s}, T)$  values as a function of temperature can be given as:

$$\Delta_{\rm f} G^{\circ}({\rm SrUO}_{3.597}, {\rm s}, T) = -1915.1 + 0.343 T$$
(25)

The first term of the above equation corresponds to enthalpy of formation at average temperature (1000 K).  $\Delta_{\rm f} H^{\circ}_{\rm m} ({\rm SrUO}_{3.597}, {\rm s}, 1000 {\rm K})$  value (-1915.1 kJ mol<sup>-1</sup>) calculated in the present work is in good agreement with  $\Delta_{\rm f} H^{\circ}_{\rm m} ({\rm SrUO}_{3.522}, {\rm s}, 298.15 {\rm K})$  value (-1893.1 kJ mol<sup>-1</sup>) determined by Takahashi et al. [15] using solution calorimetry.

By using the estimated Gibbs free energy formation values for  $SrUO_{3.597}(s)$  from Eq. (25) and that of  $TeO_2(1)$  from the literature, the standard Gibbs free energy formation of  $SrUTeO_6(s)$  could be obtained and is represented by the relation:

$$\Delta_{\rm f} G^{\circ} {\rm SrUTeO}_{6}({\rm s}) \pm 30 \, {\rm kJ/mol} = -2180.7 + 0.4263 \, T \, ({\rm K}) \, [1080 - 1162 \, {\rm K}]$$
(26)

3.3.2.  $SrUTe_2O_8$ 

SrUTe<sub>2</sub>O<sub>8</sub>(s) on heating in vacuum, during the vapour pressure measurements by the KEML technique, decomposes with the formation of SrUTeO<sub>6</sub>(s) as an intermediate product. The XRD pattern of the product obtained from the reaction was similar to that of the compound formed by heating a mixture of SrO and UTeO<sub>5</sub> in 1:1 molar proportion as discussed in Section 3.1. Hence, the decomposition of SrUTe<sub>2</sub>O<sub>8</sub>(s) could be represented as:

$$SrUTe_2O_8(s) \rightarrow SrUTeO_6(s) + TeO_2(g) [955-1041 \text{ K}]$$
(27)

Further decomposition of  $SrUTeO_6(s)$  in similar experimental conditions takes place as given in Eq. (2).

The equilibrium vapour pressure of  $\text{TeO}_2(\text{g})$  over a mixture of  $\text{SrUTe}_2\text{O}_8(\text{s})$  and  $\text{SrUTeO}_6(\text{s})$  was calculated in the temperature range of 955–1041 K for the reaction shown in Eq. (27) and the values are given in Table 4. The corresponding least squares fit of log *p* of  $\text{TeO}_2(\text{g})$  versus 1/T for  $\text{SrUTe}_2\text{O}_8$  is also shown in Fig. 2, and is represented by Eq. (28):

$$\log p (kPa) \pm 0.01 = -12446.4/T (K) + 8.9211 [955-1041 K]$$
(28)

By using the vapour pressure data of  $\text{TeO}_2(g)$ , the standard Gibbs free energy formation data of  $\text{SrUTe}_2\text{O}_8(s)$  could be obtained from the relation:

$$\Delta_{f}G^{\circ}SrUTe_{2}O_{8}(s) = \Delta_{f}G^{\circ}SrUTeO_{6}(s) + \Delta_{f}G^{\circ}TeO_{2}(l) + RT \ln \left[p_{TeO_{2}}/p_{TeO_{2}}^{\circ}\right]$$
(29)

Using the vapour pressure data of  $p_{\text{TeO}_2}$  from the experimental study of Eq. (28), the values of  $p^{\circ}_{\text{TeO}_2}$  and  $\Delta_{\text{f}}G^{\circ}\text{TeO}_2(1)$  from the literature [17,18] and the Gibbs free energy of formation of SrUTeO<sub>6</sub>(s) from Eq. (26), the Gibbs free energy formation of SrUTe<sub>2</sub>O<sub>8</sub>(s) was calculated and the values are given in Table 4, and is represented by Eq. (30)

Table 4			
Gibbs free energy of formation	of SrUTe <sub>2</sub> O <sub>8</sub> (s) at	different	temperatures

Temperature (K)	$p_{\text{TeO}_2(g)} \ (\text{kPa}) \times 10^{-4}$	$p^{\circ}_{\text{TeO}_2(s)}$ (kPa)×10 <sup>-3</sup>	$\Delta_{\rm f} G^{\circ} {\rm SrUTe}_2 {\rm O}_8({\rm s})$ (kJ mol <sup>-1</sup> )
955	0.772	3.788	-1947.2
964	1.010	5.080	-1941.9
974	1.392	6.413	- 1936.1
985	1.937	8.617	-1929.7
995	2.599	11.209	-1923.9
1000	3.004	12.759	-1921.0
1010	3.996	16.468	-1915.2
1019	5.040	20.632	-1910.0
1034	7.790	29.777	-1901.2
1041	9.030	35.211	-1897.2

$$\Delta_{\rm f} G^{\circ} {\rm SrUTe}_2 {\rm O}_8({\rm s}) \pm 30 \, {\rm kJ} \, {\rm mol}^{-1} = -2502.6$$
  
+ 0.5816 T (K) [955–1041 K] (30)

# 4. Conclusion

Two quaternary compounds  $SrUTeO_6(s)$  and  $SrUTe_2O_8(s)$  have been identified and characterised in the Sr-U-Te-O system for the first time. The lattice cell parameters for both compounds have been refined and indexed on the monoclinic system.

The thermal behaviour of both compounds has been studied using TG and DTA in air. It is observed that the decomposition of both compounds started with the loss of  $TeO_2(g)$ . The final product in air was identified as  $SrUO_4(s)$  by the XRD method. However, the final product in vacuum was identified as  $SrUO_{3.597}(s)$  for both compounds.

By using the vapour pressure data of  $\text{TeO}_2(g)$  obtained by the KEML technique, the standard Gibbs free energy formation of SrUTeO<sub>6</sub>(s) and SrUTe<sub>2</sub>O<sub>8</sub>(s) are being reported for the first time.

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