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SYNTHESIS AND STRUCTURE OF BISMUTH COMPLEXES $[p\text{-}Tol_4E]^+_3[Bi_3I_{12}]^{3-}\cdot HOCH_2CH_2OC_2H_5$ E=P, Sb

V.V. Sharutin, *vvsharutin@rambler.ru*
O.K. Sharutina, *sharutinao@mail.ru*
V.S. Senchurin, *senvl@rambler.ru*
R.M. Khisamov, *khisrm@gmail.com*
T.V. Mosunova, *wik 22@inbox.ru*
South Ural State University, Chelyabinsk, Russian Federation

The interaction of equimolar amounts of tetra-*p*-tolylphosphonium and tetra-*p*-tolylstybonium iodides with bismuth triiodide in 2-ethoxyethanol leads to formation of the complexes $[p\text{-}Tol_4E]^+_3[Bi_3I_{12}]^{3-}\cdot HOCH_2CH_2OC_2H_5$ E=P (I), Sb (II). X-ray diffraction analysis of compounds (I) and (II) has shown that in the cations of complexes I and II the coordination of phosphorus and antimony atoms is tetrahedral (angles equal: CPC 107.3(3)°–113.4(4)° (I), CSbC 105.4(3)°–113.7(3)° (II); bond lengths for P–C and Sb–C are 1.761(9)–1.815(7) Å and 2.085(8)–2.099(8) Å, respectively). In trinuclear anions $[Bi_3I_{12}]^{3-}$ the terminal fragments BiI_3 ($Bi–I_{term}$ 2.8714(5)–2.9181(5) Å (I), 2.8867(5)–2.9248(6) Å (II)) are bonded to the central bismuth atom through six μ_2-bridging iodine atoms ($Bi\text{-}I_{br}$ 3.0454(6)-3.3891(6) Å (I), 3.0595(4)–3.3694(6) Å (II)).

Keywords: bismuth triiodide, bismuth complexes $[p\text{-}Tol_4E]^+_3[Bi_3I_{12}]^{3-}\cdot HOCH_2CH_2OC_2H_5$*, E=P, Sb, synthesis, structure.*

Introduction

Ionic bismuth complexes with linear anions $[Bi_3I_{12}]^{3-}$, in which the bismuth atoms are bonded through six μ_2-bridging iodine atoms, are described in the literature as separate examples, where nitrogen-containing acyclic or heterocyclic cations stand as counter-ions [1–3]. Thus far only one similar complex with phosphonium cation is known [4]; like complexes with organoantimony cations are not known.

In the present paper we have synthesized two new phosphorus- and antimony-containing bismuth complexes $[p\text{-}Tol_4E]^+_3[Bi_3I_{12}]^{3-}\cdot HOCH_2CH_2OC_2H_5$ (E=P, Sb) with the linear anion $[Bi_3I_{12}]^{3-}$ and carried out X-ray diffraction analysis of these.

Experimental

tris(Tetra-*p*-tolylphosphonium) hexakis(μ_2-iodo)-hexaiodo-tribismuth 2-ethoxyethanol solvate (I). The solution of 0.100 g (0.19 mmol) tetra-*p*-tolylphosphonium and 0.113 g (0.19 mmol) bismuth triiodide in 15 mL 2-ethoxyethanol was obtained. The solvent was slowly evaporated. The yield was 0.142 g (65%) of orange-red crystals of complex **I** with decomposition temperature 195 °C. Found, %: C 30.83, H 2.74. For $C_{88}H_{94}O_2P_3Bi_3I_{12}$ calculated,%: C 30.54, H 2.85.

tris(Tetra-*p*-tolylstibonium) hexakis(μ_2-iodo)-hexaiodo-tribismuth 2-ethoxyethanol solvate (II). It was obtained by the similar procedure. Orange-red crystals of complex **II** were isolated (48%) with decomposition temperature 219 °C. Found, %: C 28.56, H 2.54. For $C_{88}H_{94}O_2Sb_3Bi_3I_{12}$ calculated, %: C 28.43, H 2.62.

The X-ray diffraction analyses of crystals **I** and **II** were performed on the Bruker D8 QUEST automatic four-circle diffractometer (Mo K_α-emission, λ = 0.71073 Å, graphite monochromator). The data were collected and analyzed, the unit cell parameters were refined, and the absorption correction was applied using the SMART and SAINT-*Plus* programs [5]. All calculations for structure determination and refinement were performed using the SHELXL/PC [6] and OLEX2 programs [7]. The structures were determined by the direct method and refined by the least-squares method in the anisotropic approximation for non-hydrogen atoms. The main crystallographic data and refinement results for the structure are listed in Table 1, the selected bond lengths and bond angles are given in Table 2.

The full tables of atomic coordinates, bond lengths, and bond angles were deposited with the Cambridge Crystallographic Data Centre (CCDC 1053856, 1049481; deposit@ccdc.cam.ac.uk; http://www.ccdc.cam.ac.uk).

Table 1

Crystallographic data and the experimental and structure refinement parameters for compounds I, II

Parameter	Value	
	I	II
Empirical formula	$C_{88}H_{94}O_2P_3I_{12}Bi_3$	$C_{88}H_{94}O_2Sb_3I_{12}Bi_3$
Formula weight	3426.28	3698.62
T, K	296(2)	296(2)
Crystal system	Triclinic	Triclinic
Space group	$P\bar{1}$	$P\bar{1}$
a, Å	12.4517(6)	12.4055(4)
b, Å	18.0680(9)	18.3805(5)
c, Å	24.1711(10)	24.6523(7)
α, deg	87.532(2)	87.401(2)
β, deg	87.039(2)	87.049(2)
γ, deg	75.281(2)	74.124(2)
V, Å^3	5250.0(4)	5396.8(3)
Z	4	2
ρ(calcd.), g/cm^3	2.167	2.276
μ, mm^{-1}	8.630	9.085
F(000)	3136.0	3352.0
Crystal size, mm	0.26×0.25×0.16	0.33×0.3×0.14
2θ Range of data collection, deg	4.04 – 46.56	4.1 – 53.54
Range of refraction indices	$-13 \le h \le 13$ $-20 \le k \le 20$ $-26 \le l \le 26$	$-15 \le h \le 15$ $-23 \le k \le 23$ $-31 \le l \le 31$
Measured reflections	94609	102068
Independent reflections	15056	22967
R_{int}	0.0486	0.0587
Refinement variables	990	990
GOOF	1.036	1.007
R factors for $F^2 > 2\sigma(F^2)$	R_1= 0.0361 wR_2= 0.0817	R_1 = 0.0382 wR_2 = 0.0705
R factors for all reflections	R_1= 0.0579 wR_2 = 0.0941	R_1 = 0.0711 wR_2 = 0.0811
Residual electron density (min/max), e/Å^3	1.42/–0.77	1.29/–0.92

Table 2

Selected bond lengths and bond angles in the structure of compounds 1, 2

Bond d, Å		Angle ω, deg	
I			
P(1) – C(1)	1.788(8)	C(1)P(1)C(11)	109.0(4)
P(1) – C(11)	1.800(7)	C(1)P(1)C(21)	110.0(4)
P(1) – C(21)	1.761(9)	C(1)P(1)C(31)	109.6(4)
P(1) – C(31)	1.799(8)	C(11)P(1)C(21)	110.3(4)
P(2) – C(41)	1.804(7)	C(11)P(1)C(31)	109.9(3)
P(2) – C(51)	1.791(6)	C(21)P(1)C(31)	108.0(4)

Table (continued)

Bond *d*, Å		Angle ω, deg	
I			
P(2) – C(61)	1.770(7)	C(41)P(2)C(51)	107.5(3)
P(2) – C(71)	1.795(7)	C(41)P(2)C(61)	109.6(3)
P(3) – C(81)	1.800(7)	C(41)P(2)C(71)	111.7(3)
P(3) – C(91)	1.791(7)	C(51)P(2)C(61)	109.3(3)
P(3) – C(101)	1.815(7)	C(51)P(2)C(71)	111.4(3)
P(3) – C(111)	1.800(8)	C(61)P(2)C(71)	107.3(3)
Bi(1) – I (1)	3.0748(5)	C(81)P(3)C(91)	109.7(3)
Bi(1) – I (2)	3.0706(5)	C(81)P(3)C(101)	109.1(3)
Bi(1) – I (3)	3.0444(4)	C(81)P(3)C(111)	107.7(4)
Bi(2) – I (1)	3.3046(5)	C(91)P(3)C(101)	107.8(3)
Bi(2) – I (2)	3.2715(5)	C(91)P(3)C(111)	109.1(3)
Bi(2) – I (3)	3.3556(5)	C(101)P(3)C(111)	113.4(4)
Bi(2) – I (4)	2.9181(5)	I(1)Bi(1)I(2)	91.611(13)
Bi(2) – I (5)	2.8714(5)	I(7)Bi(3)I(9)	88.583(16)
Bi(2) – I (6)	2.9049(5)	I(7)Bi(3)I(8)	85.096(15)
Bi(3) – I (7)	3.0669(5)	I(8)Bi(3)I(9)	88.406(15)
Bi(3) – I (8)	3.0654(5)	I(2)Bi(2)I(3)	79.092(13)
Bi(3) – I (9)	3.0454(6)	I(2)Bi(2)I(4)	88.012(16)
Bi(4) – I (7)	3.3153(6)	I(2)Bi(2)I(5)	93.250(16)
Bi(4) – I (8)	3.3891(6)	I(2)Bi(2)I(6)	169.597(15)
Bi(4) – I (9)	3.2907(7)	I(3)Bi(2)I(4)	94.399(15)
Bi(4) – I (10)	2.8958(6)	I(3)Bi(2)I(5)	165.035(15)
Bi(4) – I (11)	2.9040(7)	I(3)Bi(2)I(6)	92.370(15)
Bi(4) – I (12)	2.9088(7)	I(4)Bi(2)I(5)	98.194(16)
		I(4)Bi(2)I(6)	98.652(17)
		I(5)Bi(2)I(6)	93.689(17)
		I(7)Bi(4)I(8)	76.406(14)
		I(7)Bi(4)I(9)	80.500(15)
		I(7)Bi(4)I(10)	87.219(17)
		I(7)Bi(4)I(11)	93.121(18)
		I(7)Bi(4)I(12)	170.78(2)
		I(8)Bi(4)I(9)	79.245(15)
		I(8)Bi(4)I(10)	163.130(16)
		I(8)Bi(4)I(11)	87.587(17)
		I(8)Bi(4)I(12)	101.94(2)
		I(9)Bi(4)I(10)	94.251(17)
		I(9)Bi(4)I(11)	166.381(18)
		I(9)Bi(4)I(12)	90.28(2)
		I(10)Bi(4)I(11)	97.464(19)
		I(10)Bi(4)I(12)	93.58(2)
		I(11)Bi(4)I(12)	95.88(2)
II			
Sb(1) – C(1)	2.089(6)	C(1)Sb(1)C(11)	107.6(3)
Sb(1) – C(11)	2.099(8)	C(1)Sb(1)C(21)	110.8(3)
Sb(1) – C(21)	2.091(7)	C(1)Sb(1)C(31)	108.8(3)

Table (end)

Bond *d*, Å		Angle ω, deg	
II			
Sb(1) – C(31)	2.085(8)	C(11)Sb(1)C(21)	112.0(3)
Sb(2) – C(41)	2.086(7)	C(11)Sb(1)C(31)	110.9(3)
Sb(2) – C(51)	2.097(7)	C(21)Sb(1)C(31)	106.9(3)
Sb(2) – C(61)	2.097(7)	C(41)Sb(2)C(51)	109.7(3)
Sb(2) – C(71)	2.086(7)	C(41)Sb(2)C(61)	106.1(3)
Sb(3) – C(81)	2.092(8)	C(41)Sb(2)C(71)	113.6(3)
Sb(3) – C(91)	2.073(9)	C(51)Sb(2)C(61)	110.2(3)
Sb(3) – C(101)	2.090(9)	C(51)Sb(2)C(71)	105.6(3)
Sb(3) – C(111)	2.085(8)	C(61)Sb(2)C(71)	111.7(3)
Bi(1) – I (1)	3.0785(5)	C(81)Sb(3)C(91)	113.7(3)
Bi(1) – I (2)	3.0866(5)	C(81)Sb(3)C(101)	113.1(3)
Bi(1) – I (3)	3.0595(4)	C(81)Sb(3)C(111)	105.4(3)
Bi(2) – I (2)	3.3341(5)	C(91)Sb(3)C(101)	107.9(3)
Bi(2) – I (3)	3.3376(5)	C(91)Sb(3)C(111)	109.6(3)
Bi(2) – I (4)	2.9191(5)	C(101)Sb(3)C(111)	106.8(4)
Bi(2) – I (5)	2.9234(6)	I(1)Bi(1)I(2)	92.813(14)
Bi(2) – I (6)	2.8867(5)	I(1)Bi(1)I(3)	93.202(13)
Bi(3) – I (7)	3.0754(5)	I(2)Bi(2)I(3)	78.388(13)
Bi(3) – I (8)	3.0672(5)	I(2)Bi(2)I(4)	92.235(15)
Bi(3) – I (9)	3.0750(6)	I(2)Bi(2)I(5)	167.390(16)
Bi(4) – I (8)	3.3694(6)	I(2)Bi(2)I(6)	89.205(16)
Bi(4) – I (9)	3.2947(6)	I(3)Bi(2)I(4)	91.055(14)
Bi(4) – I (10)	2.9086(8)	I(3)Bi(2)I(5)	93.163(15)
Bi(4) – I (11)	2.9248(6)	I(3)Bi(2)I(6)	166.958(16)
Bi(4) – I (12)	2.9032(6)	I(4)Bi(2)I(5)	97.312(17)
		I(4)Bi(2)I(6)	93.459(17)
		I(5)Bi(2)I(6)	98.383(17)
		I(7)Bi(3)I(8)	94.620(15)
		I(7)Bi(3)I(9)	91.955(16)
		I(8)Bi(3)I(9)	88.963(16)
		I(8)Bi(4)I(9)	80.444(15)
		I(8)Bi(4)I(10)	101.90(2)
		I(8)Bi(4)I(11)	86.408(17)
		I(8)Bi(4)I(12)	163.561(19)
		I(9)Bi(4)I(10)	89.58(2)
		I(9)Bi(4)I(11)	166.666(19)
		I(9)Bi(4)I(12)	94.318(16)
		I(10)Bi(4)I(11)	95.33(2)
		I(10)Bi(4)I(12)	93.58(2)
		I(11)Bi(4)I(12)	97.730(19)

Results and Discussion

It has been shown that the interaction of equimolar amounts of tetra-p-tolylphosphonium and tetra-p-tolylstybonium iodides with bismuth triiodide in 2-ethoxyetanol leads to formation of the ionic bismuth complexes with the anion $[Bi_3I_{12}]^{3-}$, which contain the solvate molecule of the solvent:

$$3\ p\text{-}Tol_4EI + 3\ BiI_3 \xrightarrow{HOCH_2CH_2OEt} [p\text{-}Tol_4E]^+_3[Bi_3I_{12}]^{3-}\cdot HOCH_2CH_2OEt$$

E = P (**I**); Sb (**II**).

According to X-ray diffraction data, the phosphorus and antimony atoms of the cations have weakly distorted tetrahedral coordination (Fig. 1 and 2). Angles CPC and CSbC equal 107.3(3)°–113.4(4)° and 105.4(3)°–113.7(3)°, respectively. Bond lengths P–C (1.761(9)–1.815(7) Å) and Sb–C (2.085(8)–2.099(8) Å) are near to the sums of covalent radii of phosphorus, carbon (1.88 Å) and antimony, carbon (2.19 Å) [8]. In trinuclear centrosymmetrical anions $[Bi_3I_{12}]^{3-}$ the terminal fragments BiI_3 ($Bi–I_{term}$ 2.8714(5)–2.9181(5) Å (**I**), 2.8867(5)–2.9248(6) Å (**II**)) are bonded to the central bismuth atom through six μ_2-bridging iodine atoms ($Bi–I_{br}$ 3.0454(6)–3.3891(6) Å (**I**), 3.0595(4)-3.3694(6) Å (**II**)). The terminal fragments BiI_3 are in the masked conformation.

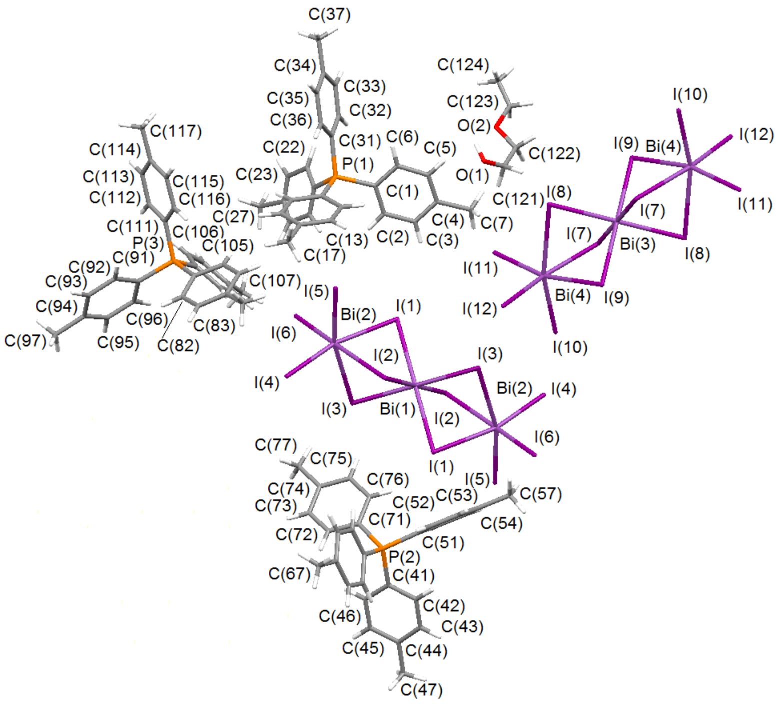


Fig. 1. The structure of complex I

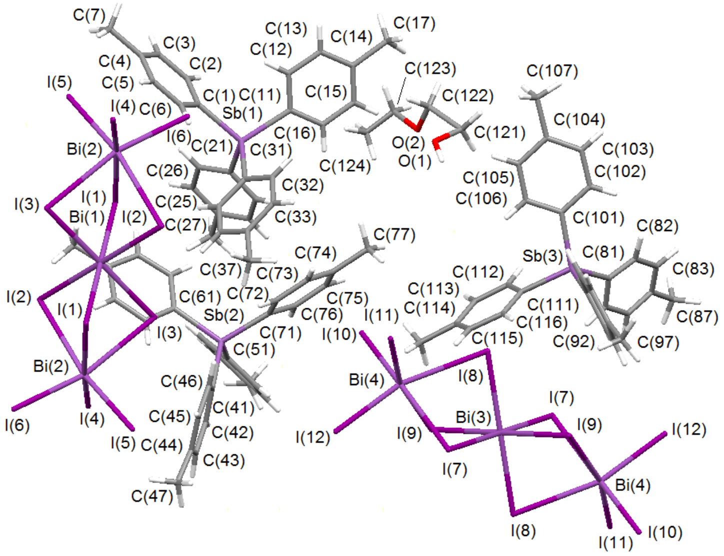
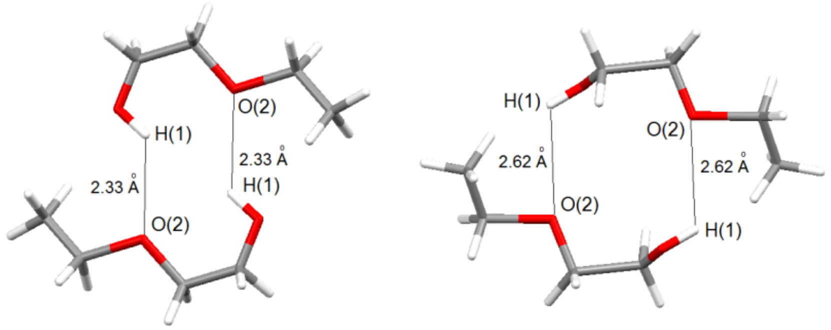


Fig. 2. The structure of complex II

The structural organization in crystals **I** and **II** results from weak interactions of the type H···I and H···O. In **I** the bridging μ_2-atoms of iodine in anions are bonded (2.86–3.16 Å) to the hydrogen atoms of phosphonium cations, in **II** the similar bonds are formed with participation of both bridging (3.10 Å) and terminal (3.15 Å) atoms of iodine (which is somewhat less than the sum of Van der Waals radii of hydrogen and iodine, namely, 3.3 Å [8]). No significant close contacts of the ions with the solvent molecules have been observed, but the molecules of 2-ethoxyethanol are bonded with each other by hydrogen bonds H···O (2.33 Å (**I**) and 2.62 Å (**II**)) (Fig. 3).



I **II**

Fig. 3. Association of solvent molecules in crystals I and II

Conclusions

Complexes $[p\text{-}Tol_4E]^+{}_3[Bi_3I_{12}]^{3-}\cdot HOCH_2CH_2OC_2H_5$ E=P (**I**), Sb (**II**) have been synthesized by interaction of equimolar amounts of tetra-*p*-tolylphosphonium and tetra-*p*-tolylstibonium iodides with bismuth triiodide in 2-ethoxyethanol. The structure of the products has been established by X-ray diffraction analysis.

References

1. Geiser U., Wade E., Wang H.H., Williams J.M. Structure of a New Iodobismuthate: Tetra(*n*-butyl)ammonium 1,2;1,2;1,2;2,3;2,3;2,3-hexa-μ-iodo-1,1,1,3,3,3-hexaiodotribismuthate (III) (3:1) *Acta Crystallographica Section C*, 1990, vol. 46, no 8, pp. 1547–1549. DOI: 10.1107/S0108270190003006

2. Carmalt C.J., Farrugia L.J., Norman N.C. Structural Studies on some Iodoantimonate and Iodobismuthate Anions *Zeitschrift für anorganische und allgemeine Chemie*, 1995, vol. 621, no. 47, pp. 47–56. DOI: 10.1002/zaac.19956210110

3. Mallick D., Sarker K.K., Saha R., Mondal T.K., Sinha C. Intercalated Iodobismuthate in the Layers of Azoimidazoles. Structure, Photochromism and DFT Computation *Polyhedron*, 2013, vol. 54, pp. 147–157. DOI:10.1016/j.poly.2013.01.061

4. Sharutin V.V., Egorova I.V., Klepikov N.N., Boyarkina E.A., Sharutina O.K. Synthesis and Structure of Bismuth Complexes $[Ph_3MeP]_6^+$ $[BiI_3Br_3]^{3-}$ $[Bi_2I_6Br_3]^{3-}\cdot H_2O_2$, $[Ph_3EtP]_3^+$ $[Bi_2I_9]^{3-}$, $[Ph_3MeP]_3^+$ $[Bi_3I_{12}]^{3-}$, $[Ph_3(iso\text{-}Pr)P]_3^+$ $[Bi_3I_{12}]^{3-}\cdot 2Me_2C{=}O$, and $[Ph_4Bi]_3^+$ $[Bi_5I_{18}]^{3-}$ *Russian Journal of Inorganic Chemistry*, 2009, vol. 54, no. 1, pp. 52–68. DOI: 10.1134/S0036023609010124

5. Bruker (1998). SMART and SAINT-Plus. Versions 5.0. Data Collection and Processing Software for the SMART System. Bruker AXS Inc., Madison, Wisconsin, USA.

6. Bruker (1998). SHELXTL/PC. Versions 5.10. An Integrated System for Solving, Refining and Displaying Crystal Structures From Diffraction Data. Bruker AXS Inc., Madison, Wisconsin, USA.

7. Dolomanov O.V., Bourhis L.J., Gildea R.J., Howard J.A.K., Puschmann H. OLEX2: a Complete Structure Solution, Refinement and Analysis Program. *J. Appl. Cryst.*, 2009, vol. 42, pp. 339–341.

8. Batsanov S.S. Atomnye Radiusy Jelementov. *Zhurn. neorgan. himii. [Russian Journal of Inorganic Chemistry],* 1991, vol. 36, no. 12, pp. 3015–3037.

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СИНТЕЗ И СТРОЕНИЕ КОМПЛЕКСОВ ВИСМУТА $[p\text{-}Tol_4E]^+_3[Bi_3I_{12}]^{3-}\cdot HOCH_2CH_2OC_2H_5$ E=P, Sb

В.В. Шарутин, О.К. Шарутина, В.С. Сенчурин, Р.М. Хисамов, Т.В. Мосунова
Южно-Уральский государственный университет, г. Челябинск

Взаимодействием эквимолярных количеств иодидов тетра-*п*-толилфосфония и тетра-*п*-толилстибония с трииодидом висмута в 2-этоксиэтаноле получены комплексы $[p\text{-}Tol_4E]^+_3[Bi_3I_{12}]^{3-}\cdot HOCH_2CH_2OC_2H_5$ E=P (I), Sb (II). Проведен рентгеноструктурный анализ I и II. В катионах координация атомов фосфора и сурьмы тетраэдрическая (углы CPC 107.3(3)°–113.4(4)° (I), CSbC 105.4(3)°–113.7(3)° (II); связи P–C 1.761(9)-1.815(7) Å (I), Sb–C 2.085(8)–2.099(8) Å (II). В трехъядерных анионах $[Bi_3I_{12}]^{3-}$ концевые фрагменты BiI_3 ($Bi\text{-}I_{терм}$ 2.8714(5)–2.9181(5) Å (I) 2.8867(5)–2.9248(6) Å (II)) связаны с центральным атомом висмута посредством шести μ_2-мостиковых атомов иода ($Bi–I_{мост}$ 3.0454(6)–3.3891(6) Å (I) 3.0595(4)–3.3694(6) Å (II)).

Ключевые слова: трииодид висмута, комплексы висмута $[p\text{-}Tol_4E]^+_3[Bi_3I_{12}]^{3-}\cdot HOCH_2CH_2OC_2H_5$, *E=P, Sb, синтез, строение.*

Литература

1. Structure of a New Iodobismuthate: Tetra(*n*-butyl)ammonium 1,2;1,2;1,2;2,3;2,3;2,3-hexa-μ-iodo-1,1,1,3,3,3-hexaiodotribismuthate (III) (3:1) / U. Geiser, E. Wade, H.H. Wang, J.M. Williams // *Acta Crystallographica Section C*, 1990. – V. 46, № 8. – P. 1547–1549.

2. Carmalt, C.J. Structural Studies on some Iodoantimonate and Iodobismuthate Anions / C.J. Carmalt, L.J. Farrugia, N.C. Norman // Zeitschrift für anorganische und allgemeine Chemie. – 1995. – V. 621, №. 47. – P. 47–56.

3. Intercalated Iodobismuthate in the Layers of Azoimidazoles. Structure, Photochromism and DFT Computation / D. Mallick, K.K. Sarker, R. Saha, T.K. Mondal et al. // Polyhedron. – 2013. – V. 54, P. 147–157.

4. Synthesis and Structure of Bismuth Complexes $[Ph_3MeP]_6^+$ $[BiI_3Br_3]^{3-}$ $[Bi_2I_6Br_3]^{3-}\cdot H_2O_2$, $[Ph_3EtP]_3^+$ $[Bi_2I_9]^{3-}$, $[Ph_3MeP]_3^+$ $[Bi_3I_{12}]^{3-}$, $[Ph_3(iso\text{-}Pr)P]_3^+$ $[Bi_3I_{12}]^{3-}\cdot 2Me_2C{=}O$, and $[Ph_4Bi]_3^+$ $[Bi_5I_{18}]^{3-}$ / V.V. Sharutin, I.V. Egorova, N.N. Klepikov, E.A. Boyarkina et al // Russian Journal of Inorganic Chemistry. – 2009. – V. 54, № 1. – P. 52–68.

5. Bruker (1998). SMART and SAINT-Plus. Versions 5.0. Data Collection and Processing Software for the SMART System. Bruker AXS Inc., Madison, Wisconsin, USA.

6. Bruker (1998). SHELXTL/PC. Versions 5.10. An Integrated System for Solving, Refining and Displaying Crystal Structures From Diffraction Data. Bruker AXS Inc., Madison, Wisconsin, USA.

7. OLEX2: a Complete Structure Solution, Refinement and Analysis Program / O.V. Dolomanov, L.J. Bourhis, R.J. Gildea et al. // J. Appl. Cryst. – 2009. – V. 42. – P. 339–341.

8. Бацанов, С.С. Атомные радиусы элементов / С.С. Бацанов // Журн. неорган. химии. – 1991. – Т. 36. – № 12. – С. 3015–3037.

Шарутин Владимир Викторович – доктор химических наук, профессор, старший научный сотрудник УНИД, Южно-Уральский государственный университет. 454080, г. Челябинск, пр. им. В.И. Ленина, 76. E-mail: vvsharutin@rambler.ru

Шарутина Ольга Константиновна – доктор химических наук, профессор, кафедра аналитической химии, Южно-Уральский государственный университет. 454080, г. Челябинск, пр. им. В.И. Ленина, 76. E-mail: sharutinao@mail.ru

Сенчурин Владислав Станиславович – кандидат химических наук, доцент, кафедра органической химии, Южно-Уральский государственный университет. 454080, г. Челябинск, пр. им. В.И. Ленина, 76. E-mail: senvl@rambler.ru

Хисамов Радмир Мухаметович – студент химического факультета, Южно-Уральский государственный университет. 454080, г. Челябинск, пр. им. В.И. Ленина, 76. E-mail: khisrm@gmail.com

Мосунова Татьяна Владимировна – кандидат химических наук, доцент, кафедра экологии и природопользования, химический факультет, Южно-Уральский государственный университет. 454080, г. Челябинск, пр. им. В.И. Ленина, 76. E-mail: wik22@inbox.ru

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