# Zinc Iodide Complexes of Propaneamide, Benzamide, Dimethylurea, and **Thioacetamide: Syntheses and Structures**

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Abstract. Complexes of zinc iodide with propaneamide EtCONH<sub>2</sub>, benzamide BzNH<sub>2</sub>, dimethylurea MeNHCONHMe, and thioacetamide MeCSNH<sub>2</sub> have been synthesized and characterized by elemental analyses, vibrational spectra and X-ray diffraction. The vibrational spectra indicate coordination of amides through oxygen atoms. The elemental analyses have justified the complexes with the

ZnI<sub>2</sub>/L ratio of 1:3 for propaneamide and 1:2 for other amides. The X-ray study has shown that the complexes have different coordination modes. The complexes of benzamide, dimethylurea, and thioacetamide are molecular, [ZnL2I2], and the complex of propaneamide is ionic, [ZnL<sub>6</sub>][ZnI<sub>4</sub>]. Structures of zinc and cadmium complexes with various amides are compared.

# Introduction

This work continues the systematic study of 12 group metal iodide complexes with amides and thioamides [1-5]. These compounds can be used for the synthesis of the corresponding polyiodides [6, 7] and nano-size forms of metals or metal oxides and sulfides [8, 9].

The zinc iodide complex with acetamide (AA)  $[Zn(AA)_2I_2]$ and cadmium complexes with thioacetamide (TAA) and benzamide (BA), [Cd(TAA)<sub>2</sub>I<sub>2</sub>] and [Cd(BA)<sub>4</sub>I<sub>2</sub>], are molecular [1, 2, 5], whereas the cadmium iodide complexes with acetamide and propaneamide (PA)  $[CdL_6][Cd_2I_6]$  (L = AA, PA) are ionic [3]. For the zinc iodide complex with propaneamide, only vibrational spectra were reported [10]. Zinc iodide forms a molecular complex with urea  $(Ur) [Zn(Ur)_2I_2]$ [11], and cadmium iodide forms an ionic complex with urea [Cd(Ur)<sub>6</sub>][CdI<sub>3</sub>]<sub>2</sub> [12] and a molecular complex with 1,3-dimethylurea (DMU) [Cd(DMU)<sub>3</sub>I<sub>2</sub>] [4].

The variability of coordination modes and structures of metal iodide complexes with amides stimulated further synthesis of new complexes with relative ligands. The purpose

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of the work was to synthesize and study structures of zinc iodide complexes with propaneamide, benzamide, 1,3-dimethylurea, and thioacetamide.

### **Experimental Section**

Syntheses: Zinc iodide (1 g, 3.13 mmol) and the Ligand L (L = BA, PA, DMU, TAA) (6.26 mmol) were dissolved in EtOH (for L = BA) or MeCN (L = PA, DMU, TAA) (10 mL). The solution was layered on to a liquid perfluorinated hydrocarbon, 1-methyldecahydronaphthalene, allowing formation of colorless crystals (yields were 50, 65, 56, and 40 % for L = PA, BA, DMU, and TAA, respectively). All complexes were stable in air excluding [Zn(TAA)<sub>2</sub>I<sub>2</sub>], which decomposed within a few hours. M.p.:  $[Zn(PA)_6][ZnI_4]$ , 51.0-52.5 °C;  $[Zn(BA)_2I_2]$ , 124.0-125.5 °C; [Zn(DMU)<sub>2</sub>I<sub>2</sub>], 114.0-115.0 °C.

Elemental Analysis for the Complexes: [Zn(PA)<sub>6</sub>][ZnI<sub>4</sub>] (1076.92): calcd C 19.96, H 3.88, N 7.76, Zn 12.01; found C 18.97, H 2.98, N 7.34, Zn 12.88. [Zn(BA)<sub>2</sub>I<sub>2</sub>] (561.44): calcd. C 28.52, H 2.38, N 4.75, Zn 11.65; found C 28.72, H 2.92, N 4.85, Zn 11.98. [Zn(DMU)<sub>2</sub>I<sub>2</sub>] (495.40): calcd. Zn 13.13, C 14.55, N 11.31, H 3.23; found C 14.87, H 3.27, N 12.08, Zn 12.95.

[Zn(PA)<sub>6</sub>][ZnI<sub>4</sub>] is soluble in H<sub>2</sub>O, EtOH, Me<sub>2</sub>CO, and MeCN; [Zn(BA)<sub>2</sub>I<sub>2</sub>] is soluble in EtOH and Me<sub>2</sub>CO, poorly soluble in H<sub>2</sub>O, and insoluble in CHCl<sub>3</sub>; [Zn(DMU)<sub>2</sub>I<sub>2</sub>] is soluble in H<sub>2</sub>O, EtOH, and Me<sub>2</sub>CO, insoluble in CHCl<sub>3</sub>; [Zn(TAA)<sub>2</sub>I<sub>2</sub>] is soluble in H<sub>2</sub>O, EtOH, Me<sub>2</sub>CO, and MeCN, insoluble in CHCl<sub>3</sub>. Specific conductivities (measured with a OK 102/1 conductometer) of 0.001 M aqueous solutions of [Zn(BA)<sub>2</sub>I<sub>2</sub>] and [Zn(DMU)<sub>2</sub>I<sub>2</sub>] (85 and 435  $\mu$ S·cm<sup>-1</sup>) indicated that [Zn(BA)<sub>2</sub>I<sub>2</sub>] is stable, while [Zn(DMU)<sub>2</sub>I<sub>2</sub>] decomposed under dissolution in water.

X-ray Diffraction: Details of the X-ray analysis are summarized in Table 1.



1458

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**Table 1.** Crystallographic characteristics, experimental details, and refinement parameters for the structures of  $[Zn(PA)_6][ZnI_4]$  (I),  $[Zn(DMU)_2I_2]$  (II),  $[Zn(BA)_2I_2]$  (III), and  $[Zn(TAA)_2I_2]$  (IV).

Parameter	Ι	II	III	IV
Formula weight	2153.83	495.40	561.44	469.43
Crystal system	triclinic	triclinic	monoclinic	monoclinic
Space group	$P\overline{1}$	$P\overline{1}$	$P2_1/c$	$P2_1/c$
Crystal size /mm	0.1  imes 0.1  imes 0.1	0.1  imes 0.1  imes 0.1	$0.1 \times 0.1 \times 0.1$	$0.4 \times 0.4 \times 0.4$
a /Å	10.8300(62)	7.122(3)	8.458(4)	7.551(4)
b /Å	18.3901(34)	8.310(4)	15.174(6)	23.518(13)
c /Å	19.0861(38)	12.868(6)	14.294(5)	7.814(5)
$\alpha$ /deg	93.498(15)	83.61(4)	90	90
$\beta$ /deg	94.103(36)	79.18(4)	98.25(3)	114.03(5)
γ /deg	92.090(36)	80.72(4)	90	90
V/Å <sup>3</sup>	3799.7	735.7	1815.5	1267.3
Ζ	2	2	4	4
<i>T</i> /K	293(2)	293(2)	293(2)	293(2)
$d_{\rm c}/{\rm mg}\cdot{\rm m}^{-3}$	1.883	2.236	2.054	2.460
λ/Å	0.71073	0.71073	1.54180	0.71073
$\theta$ Range	1.07 - 24.99	1.62 - 27.97	4.27-69.91	1.73 - 26.00
$\mu / \text{mm}^{-1}$	4.546	5.856	28.623	7.094
F(000)	2048	464	1056	864
Reflns. collected	10186	3532	3246	2484
Reflns. unique	4952	3007	2770	1683
R, all data	0.1419	0.0415	0.0762	0.0861
$R, I > 2\sigma(I)$	0.0686	0.0340	0.0704	0.0568
wR, all data	0.1902	0.0887	0.1867	0.1519
$wR, I > 2\sigma(I)$	0.1555	0.0851	0.1792	0.1354
Goodness-of-fit on $F^2$	0.935	1.017	1.057	0.956
$\Delta \rho_{\rm min} / e \cdot {\rm \AA}^{-3}$	-1.007	-0.748	-1.235	-1.144
$\Delta \rho_{\rm max} / e \cdot {\rm \AA}^{-3}$	1.023	0.868	2.726	1.603

Crystallographic data for the structure(s) have been deposited with the Cambridge Crystallographic Data Centre under CCDC-695546 (I), -695546 (II), -695547 (III), -695544 (IV). Copies of the data can be obtained free of charge on application to The Director, CCDC, 12 Union Road, Cambridge CB2 1EZ, UK [Fax: +44-1223-336-033; E-Mail for inquiry: fileserv@ccdc.cam.ac.uk; E-Mail for deposition: deposit@ccdc.cam.ac.uk].

The experimental intensities of the diffraction reflections were collected at room temperature with a CAD-4 automated diffractometer (Cu- $K_{\alpha}$  or Mo- $K_{\alpha}$ , graphite monochromator, non-profiled  $\omega$  scans,  $\gamma$  scan absorption correction). The structures were solved by the direct method and refined by the full-matrix leastsquares technique against  $F^2$  in the anisotropic approximation for non-hydrogen atoms. The positions of hydrogen atoms were calculated and refined in an isotropic approximation in a riding model. All calculations were performed using SHELXS-97 and SHELXL-97 [13].

**Spectra:** IR spectra were recorded with Infralum FT-02  $(500-4000 \text{ cm}^{-1}, \text{ nujol mulls})$  and Bruker EQUINOX 55/SB  $(400-4000 \text{ cm}^{-1}, \text{ KBr pellets})$  spectrometers at room temperature.

Raman spectra were excited by a 1064 nm Nd:YAG laser radiation at room temperature and recorded using a Bruker Fourier-Raman spectrometer RFS 100/S ( $80-3000 \text{ cm}^{-1}$ ) with the resolution of 2 cm<sup>-1</sup>.

# Results

#### **Crystal Structures**

The crystal of  $[Zn(PA)_6][ZnI_4]$  is built from the  $[Zn(PA)_6]^{2+}$  and  $[ZnI_4]^{2-}$  ions. The zinc atom is octa-



Figure 1. [Zn(PA) <sub>6</sub> ][	ZnI <sub>4</sub> ]. Selec	ted bond lengths /Å	and bond
angles /º: Zn(1)-I(4	) 2.593(2),	Zn(1)-I(3) 2.602(2), Z	Zn(1) - I(2)
2.6142(19), Zn(1)-	-I(1) 2.63	$Z_{1(2)}, Z_{n(3)} - O(7)$	2.066(9),
Zn(3)-O(13) 2.082	(9), Zn(3)	-O(16) 2.090(9), Z	n(3) - O(4)
2.092(9), Zn(3)-C	D(10) 2.09	25(9), Zn(3) - O(1)	2.097(9);
I(4) - Zn(1) - I(3)	111.03(7),	I(4) - Zn(1) - I(2)	110.92(8),
I(3) - Zn(1) - I(2)	113.67(8),	I(4) - Zn(1) - I(1)	108.77(8),
I(3) - Zn(1) - I(1)	106.15(7),	I(2) - Zn(1) - I(1)	105.94(7),
O(7) - Zn(3) - O(13)	91.1(4),	O(7) - Zn(3) - O(16)	85.0(4),
O(13)-Zn(3)-O(16)	90.9(4),	O(7) - Zn(3) - O(4)	91.7(4),
O(13) - Zn(3) - O(4)	93.1(4),	O(16) - Zn(3) - O(4)	174.8(4),
O(7) - Zn(3) - O(10)	175.9(3),	O(13) - Zn(3) - O(10)	86.5(4),
O(16)-Zn(3)-O(10)	91.8(4),	O(4) - Zn(3) - O(10)	91.7(4),
O(7) - Zn(3) - O(1)	90.0(4),	O(13) - Zn(3) - O(1)	176.9(4),
O(16) - Zn(3) - O(1)	92.0(4),	O(4) - Zn(3) - O(1)	84.0(4),
O(10) - Zn(3) - O(1)	92.6(4).		

hedrally coordinated by oxygen atoms of the ligand in the cation and tetrahedrally coordinated by iodine atoms in the anion (Figure 1).

In both independent cations, five propaneamide ligands are planar with respect to the metal (the M–O–C–N torsion angles < 17°); while the sixth ligand is essentially nonplanar (the M–O–C–N torsion angles are 44.90 and 46.51°). This is not typical for transition metal complexes of amides [14]. In contrast to the zinc–acetamide complex [1], where three of four independent ligands have nitrogen atoms in *trans*-positions to the metal atom, in [Zn(PA)<sub>6</sub>][ZnI<sub>4</sub>], the metal lying in the amide plane is always *cis* to N. The cation is stabilized by six intermolecular N–H···O hydrogen bonds. Every iodine atom in the anion is involved in short N–H···I contacts with adjacent cations.

The crystals of  $[ZnL_2I_2]$  (L = BA, DMU) are built of the corresponding molecular complexes (Figure 2, Figure 3). The zinc atom is tetrahedrally coordinated by two oxygen atoms of two amide ligands and two iodine atoms. The Zn-O and Zn-I bonds in the benzamide and 1,3-dimeth-ylurea complexes are slightly shorter than in the propane-amide complex. In the planar Zn-O-C-N groups (the torsion angle < 9°) of [Zn(BA)<sub>2</sub>I<sub>2</sub>], the metal is always *cis* to N.

The structure of each complex is stabilized by a single intramolecular N-H...O hydrogen bond. All iodine atoms are involved in short N-H...I contacts with adjacent molecules. Both structures are layered.



Figure 2.  $[Zn(BA)_2I_2]$ . Selected bond lengths /Å and bond angles /°: Zn(1)-O(1) 1.954(5), Zn(1)-O(2) 2.026(5), Zn(1)-I(1) 2.5316(10), Zn(1)-I(2) 2.5273(11); O(1)-Zn(1)-O(2) 97.7(2), O(1)-Zn(1)-I(2) 110.31(19), O(2)-Zn(1)-I(2) 111.51(18), O(1)-Zn(1)-I(1) 109.6(2), O(2)-Zn(1)-I(1) 105.51(18), I(1)-Zn(1)-I(2) 119.84(4).

The structure of  $[Zn(DMU)_2I_2]$  differs drastically from  $[Zn(DMU)_6](CIO_4)_2$ , which is built of  $[Zn(DMU)_6]^{2+}$  cations and  $CIO_4^-$  counterions [15].

The crystal of  $[Zn(TAA)_2I_2]$  has the similar structure (Figure 4). The metal lies in the thioacetamide planes (the Zn-S-C-N torsion angles are 1.54° and 3.59°) and is *cis* to nitrogen. No intramolecular hydrogen bonds are found in the complex molecule. One iodine atom is involved in two N-H···I short contact, and another, in one C-H···I



Figure 3.  $[Zn(DMU)_2I_2]$ . Selected bond lengths /Å and bond angles /°: Zn(1)-O(1) 1.958(3), Zn(1)-O(2) 1.986(3), Zn(1)-I(1) 2.5572(15), Zn(1)-I(2) 2.5668(12), O(1)-Zn(1)-O(2) 101.23(13), O(1)-Zn(1)-I(1) 108.76(12), O(2)-Zn(1)-I(1) 109.91(11), O(1)-Zn(1)-I(2) 111.24(11), O(2)-Zn(1)-I(1) 110.84(10), I(1)-Zn(1)-I(2) 114.08(4).

contact, forming infinite layer. The layers are combined in a 3D-structure by the C-H···S short contacts. The structure is similar to  $[Zn(TAA)_2Cl_2]$  [16].



Figure 4.  $[Zn(TAA)_2 I_2]$ . Selected bond lengths /Å and bond angles /°: I(1)-Zn(1) 2.5780(19), I(2)-Zn(1) 2.5782(19), Zn(1)-S(1) 2.339(2), Zn(1)-S(2) 2.352(3); S(1)-Zn(1)-S(2) 97.35(10), S(1)-Zn(1)-I(1) 113.87(9), S(2)-Zn(1)-I(1) 112.16(9), S(1)-Zn(1)-I(2) 112.23(9), S(2)-Zn(1)-I(2) 111.92(9), I(1)-Zn(1)-I(2) 109.00(7).

#### IR and Raman Spectra

Vibrational spectra of the zinc iodide complex with propaneamide are discussed in [10]. Shifts of the main bands indicate that propaneamide ligand is bounded to zinc through the amide oxygen.

In the 50–300 cm<sup>-1</sup> range, four modes of the tetrahedral  $[\text{ZnI}_4]^{2-}$  ion are active in Raman spectra:  $v_1(A_1)$ ,  $v_2(E)$ ,  $v_3(F_2)$ ,  $v_4(F_2)$  [17]. The Raman spectrum of  $[\text{Zn}(\text{PA})_6][\text{ZnI}_4]$  reveals strong bands at 120 cm<sup>-1</sup> ( $v_1$ ) and 172 cm<sup>-1</sup> ( $v_3$ ). The intensity ratio agrees with literature data:  $v_3 > v_1$  [17]. The bands below 100 cm<sup>-1</sup> ( $v_2$  and  $v_4$ ) overlap with the laser band.

The full vibrational analysis of crystalline DMU has been published [18]. To elucidate the shifts of the v(C-O) and



 $\delta_{as}(N-H)$  bands, IR spectra of the deuterated complex was recorded. Table 2 gives diagnostic IR and Raman bands of the free ligand and its complex with zinc iodide. Assignments in Table 2 have been given in comparison with the data obtained for the uncoordinated DMU [18] and its cobalt complexes [19]. In the IR and Raman spectra of  $[Zn(DMU)_2I_2]$ , the frequency of the C=O stretching mode decreases as compared to the spectra of the free ligand indicating coordination of the ligand through the oxygen atom. Upon coordination through oxygen, the positively charged metal ion stabilizes the negative charge on the oxygen atom; the N-C=O group now occurs in its polar resonance form and the double bond character of the C-N bond increases, while the double bond character of the C=O bond decreases, resulting in an increase of the C-N stretching frequency with a decrease in the C=O stretching frequency [17]. Increase of the frequencies of the N-H stretching mode is caused by rearrangement of electron density in the ligand molecules.

 Table 2. IR/Raman spectra of DMU and deuterated DMU and their zinc iodide complexes.

Assignment	DMU	$[Zn(DMU)_2I_2]$	[D <sub>2</sub> ]DMU	$[Zn([D_2]DMU)I_2]$
$v_{\rm s}(\rm N-H)$	3360	3368/3373	2496	2518
$v_{as}(N-H)$	3348/3339		2482	2491
v(C-O)	1627/1621	1581/1591	1627	1580
$\delta_{\rm as}(\rm NH)$	1591	1612/1602	1517	1559
$v_{as}(C-N)$	1270	1270/1284	1336	1369
$v_{s}(N-R)$	1175/1191	1174/1179	1165	1162
$v_{as}(N-R)$	1040	1042/1048	1027, 982	1044, 953
$v_{s}(C-N)$	931/930	896/899	950, 917	882
$\pi(C-O)$	775	763	765	762
$\delta(C-O)$	702		679	641
$\delta(NCN)$	496/508		473	
v(M-O)				552

Similar shifts of principle bands were found in the IR spectrum of the benzamide complex. The Raman spectrum of benzamide does not change significantly on complexation.

From nine bands, which are active for molecular complexes [ZnL<sub>2</sub>I<sub>2</sub>], several bands were found in the Raman spectra of the complexes. The bands at 119, 150, 170, and 201 cm<sup>-1</sup> in the spectrum of [Zn(DMU)<sub>2</sub>L<sub>2</sub>] are assigned to the Zn-I vibration modes, and the bands at 515, 570, and 650 cm<sup>-1</sup> are assigned to the Zn-O vibration modes. In the spectrum of [Zn(BA)<sub>2</sub>I<sub>2</sub>], these bands are found at 122, 145, 155, 189, and 428 cm<sup>-1</sup>.

Vibrational spectra of  $[Zn(TAA)_2I_2]$  were not studied because the compound decomposed under sampling.

### Discussion

The zinc iodide complex of thioacetamide is similar to the cadmium iodide complex of the same ligand [2]. Both complexes are molecular with the tetrahedral coordination of the central atom. Similar structure was reported for the dimethylacetamide (DMA) complex from zinc iodide  $[Zn(DMA)_2I_2]$  [20]. In the zinc iodide complexes of dimethylurea and benzamide  $[ZnL_2I_2]$ , the coordination number (CN) for zinc is also 4, whereas CNs for cadmium in  $[Cd(DMU)_3I_4]$  [4] and  $[Cd(BA)_4I_2]$  [5] are 5 and 6, respectively. Both zinc and cadmium complexes with propaneamide are ionic, differing by the complex anion ( $[ZnI_4]^2$  and  $[Cd_2I_6]^2$  [3], respectively). Summary of all reported data on the structures of zinc and cadmium iodides with relative ligands allows discussing effects of various factors on complex formation.

Combination of inductive and mesomeric effects increases donating ability of the oxygen atom in the row  $BA \approx DMU \approx DMA < Ur \approx AA < PA$ . According to this row, high donating ability of propaneamide allows it to substitute all iodine atoms in the inner sphere of both zinc and cadmium central atoms resulting in formation of ionic complexes (Table 3). Acetamide and urea ligands substitute iodine atoms in the inner sphere of the softer cadmium atom and form the inner sphere along with the iodine atoms in the complexes of the harder zinc atom. Neither dimethylurea, nor benzamide substitute iodine atoms in the inner spheres of both zinc and cadmium atoms. These ligands form molecular complexes with both central atoms. Dimethylacetamide forms similar molecular complex with zinc iodide.

Table 3. Zinc and cadmium iodide complexes with amides.

Ligand	Zinc complex	Cadmium complex
Propaneamide (PA)	$[Zn(PA)_6][ZnI_4]$	[Cd(PA) <sub>6</sub> ][Cd <sub>2</sub> I <sub>6</sub> ] [3]
Acetamide (AA)	$[Zn(AA)_2I_2]$ [2]	$[Cd(AA)_6][Cd_2I_6][3]$
Urea (Ur)	$[Zn(Ur)_2I_2]$ [11]	$[Cd(Ur)_6][CdI_3]$ [12]
1,3-Dimethylurea (DMU)	$[Zn(DMU)_2I_2]$	$[Cd(DMU)_{3}I_{2}]$ [4]
Dimethylacetamide (DMA)	$[Zn(DMA)_2I_2]$ [20]	no data
Benzamide (BA)	$[Zn(BA)_2I_2]$	$[Cd(BA)_4I_2][1]$
Thioacetamide (TAA)	$[Zn(TAA)_2I_2]$	$[Cd(TAA)_2I_2]$ [5]
Thiourea (TUr)	no data	[Cd(TUr) <sub>2</sub> I <sub>2</sub> ] [21]

Differences in CN seem to be caused by steric factors. Zinc shows CN 4, when its coordination sphere contains large iodine atoms. If it is coordinated by oxygen atoms only, its CN increases up to 6. Cadmium shows CN 4 only in the  $[Cd_2I_6]^{2-}$  anion. If cadmium is coordinated by oxygen atoms, its CN increases up to 5 in the complex of dimethylurea and 6 in complexes of BA, Ur, AA, and PA. Although the dimethylurea molecule is not larger than the benzamide or propaneamide molecule, it has a fork just nearby the donating atom producing steric hindrances.

For thioamides, inductive and mesomeric effects are of less importance. In the zinc iodide and cadmium iodide complexes of thioacetamide [2] and cadmium iodide complex of thiourea (TUr) [Cd(TUr)<sub>2</sub>I<sub>2</sub>] [21], soft sulfur and iodine atoms are equal when forming the inner sphere. Large size of the iodine and sulfur atoms results in CN 4 for the complexes of thioacetamide and thiourea.

Supporting Information (see footnote on the first page of this article): Positional and thermal displacement parameters for I-IV.

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### References

- N. E. Kuz'mina, K. K. Palkina, E. V. Savinkina, I. A. Zamilatskov, *Russ. J. Inorg. Chem.* 2005, 50, 1521–1524.
- [2] E. V. Savinkina, E. A. Buravlev, I. A. Zamilatskov, D. V. Albov, Acta Crystallogr, Sect. E 2007, 63, m1094–1095.
- [3] I. A. Zamilatskov, E. V. Savinkina, D. V. Al'bov, Russ. J. Coord. Chem. 2007, 33, 396–399.
- [4] E. V. Savinkina, I. A. Zamilatskov, D. V. Albov, M. G. Zaitseva, V. V. Kravchenko, *Acta Crystallogr., Sect. E* 2007, 63, m1335–1336.
- [5] I. A. Zamilatskov, E. A. Buravlev, E. V. Savinkina, N. S. Roukk, D. V. Albov, *Acta Crystallogr., Sect. E* 2007, 63, m2669-2670.
- [6] E. V. Savinkina, I. A. Zamilatskov, Ya. F. Al Ansari, D. V. Albov, A. Yu. Tsivadze, *Acta Crystallogr., Sect. E* 2005, 61, m2371-2372.
- [7] E. V. Savinkina, D. V. Al'bov, E. A. Buravlev, I. A. Zamilatskov, *Russ. J. Inorg. Chem.* 2007, 52, 1056–1062.
- [8] Zh. Zhang, H. Yu, Yu. Wang, M.-Y. Han, Nanotechnology 2006, 17, 2994–2997.
- [9] C. M. López, K.-Sh. Choi, Langmuir 2006, 22, 10625-10629.

- [10] A. Yu. Tsivadze, A. N. Smirnov, Yu. Ya. Kharitonov, G. V. Tsintsadze, M. N. Tevzadze, *Koord. Khim.* 1977, 3, 516–523.
- [11] N. G. Furmanova, V. F. Resnyanskii, K. S. Sulaimankulov, Sh. Zh. Zhorobekova, D. K. Sulaimankulova, *Cryst. Rep.* 2001, 46, 51–55.
- [12] N. G. Furmanova, V. F. Resnyanskii, D. K. Sulaimankulova, Sh. Zh. Zhorobekova, K. S. Sulaimankulov, *Cryst. Reports* 1997, 42, 421–424.
- [13] G. M. Sheldrick, SHELXS97 and SHELXL97, University of Göttingen, Germany, 1997.
- [14] O. Clement, B. M. Rapko, B. P. Hay, Coord. Chem. Rev. 1998, 170, 203-243.
- [15] R. Keuleers, H. O. Desseyn, S. Papaefstathiou, L. Drakopoulou, S. P. Perlepes, C. P. Raptopoulou, A. Terzis, *Transition Met. Chem.* 2003, 28, 548–557.
- [16] M. M. Rolies, C. J. De Ranter, Cryst. Struct. Commun. 1977, 6, 275–280.
- [17] K. Nakamoto, Infrared spectra of inorganic and coordination compounds, Wiley, New York, 1986.
- [18] R. Keuleers, H. O. Desseyn, B. Rousseau, C. Van Abenoy, J. Phys. Chem. A 2000, 104, 5946-5954.
- [19] G. S. Papaefstathiou, R. Keuleer, C. J. Milios, C. P. Raptopoulou, A. Terzis, H. O. Desseyn, S. P. Perlepes, Z. Naturforsch. Teil B 2003, 58, 74–84.
- [20] C. J. Wilkins, M. M. Yurnbull, J. L. Wikaira, Z. Kristallogr. 2002, 215, 702.
- [21] C. Marcos, J. M. Aha, V. Adovasio, M. Prieto, S. García-Granda, Acta Crystallogr., Sect. C 1998, 54, 1225–1229.

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