Synthesis, structure, and properties of new spirooxindolodibenzodiazepine derivatives

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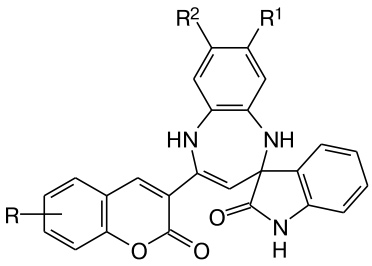
An acid-catalyzed reaction of 3-(2-aminophenylamino)-5,5-dimethylcyclohexen-1-one with isatines leads to the formation of the earlier undescribed 3,3-dimethyl-2,3,4,5,10,11-hexahydrospiro[1*H*-dibenzo[*b*,*e*][1,4]diazepine-11,3′-2*H*-indole]-1,2′-dione derivatives (**6**). Spiranes **6** upon heating undergo auto-redox rearrangement with disintegration to 3,3-dimethyl-1,2,3,4-tetrahydrophenazine and the corresponding oxindole. Crystals of four derivatives of compound **6** were studied by X-ray diffraction method.

Key words: 3-(2-aminophenylamino)-5,5-dimethylcyclohexen-1-one, isatines, acid catalysis, spiro-oxindolodibenzodiazepine derivatives, X-ray diffraction analysis.

An ability to the formation of spiro compounds at position C(3) in the reactions with nucleophiles and dipolarophiles is a characteristic feature of isatines, which is reflected in the reviews.[1—3] The constantly growing interest of chemists to isatines is explained by their synthetic versatility and biological activity frequently exhibited by compounds derived from them. In the majority of described spirooxindoles, the isatine fragment is spirocoupled with the five- or six-membered rings.[1—3]

Only several examples of the oxindole fragment spirocoupled with the seven-membered heterocycles are known. The compounds structurally the closest to those described by us below, *viz.*, spirooxindolobenzodiazepines **1**, were obtained by the reaction of the products of condensation of isatine and 3-acetylcoumarins with *o*-phenylenediamine.[4] Compounds **1** were tested in mice as potential tranquilizing agents, as well as *in vitro* on the antibacterial activity.[4]

The work[5] described a stereocontrolled synthesis of *cis*- and *trans*-spirooxindolooxepenes **2** by the [5+2]-cycloaddition of chiral crotylsilanes bearing primary alcohol group and isatine dimethyl ketal. A one-pot three-component synthesis leading to spiroindoline-3,4′-pyrazolo[3,4-*e*][1,4]thiazepinediones **3** was reported recently.[6]



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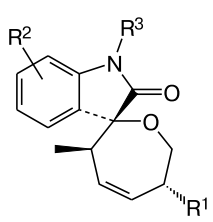
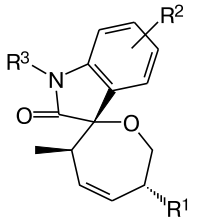
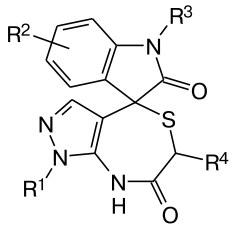


cis-**2**



trans-**2**



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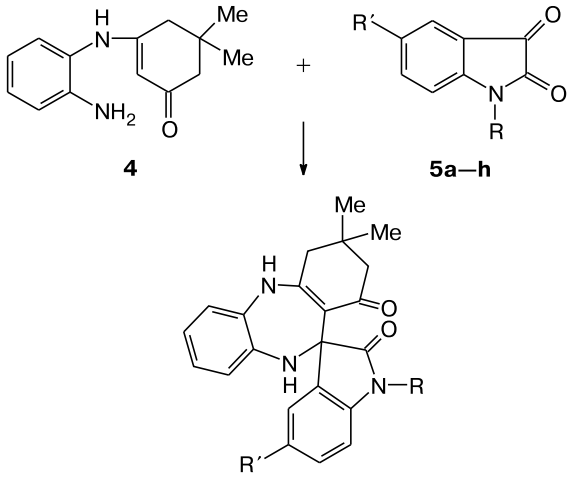
† Deceased.

Published in Russian in *Izvestiya Akademii Nauk. Seriya Khimicheskaya,* No. 6, pp. 1409—1416, June, 2013.

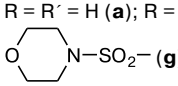
In the present work, we suggest a one-pot synthesis of the earlier unknown spirooxindolodibenzodiazepine derivatives. In continuation of our studies on the reactions of 3-(2-aminophenylamino)-5,5-dimethylcyclohexen-1-one (**4**),[7–9] we found that its heating in EtOH with the equivalent amounts of isatines **5a—h** in the presence of a catalytic amount of CF_3COOH led to the condensation to spirooxindolobenzodiazepines **6a—h** (Scheme 1).

Scheme 1



Reagents and conditions: EtOH, CF_3COOH, Δ, $-H_2O$.

R = R′ = H (**a**); R = H, R′ = Me (**b**); MeO (**c**); F (**d**); Cl (**e**); Br (**f**);



(**g**); R = CH_2OH, R′ = H (**h**)

The formation of spiranes **6** proceeded rapidly and in high yields. The IR and ^1H NMR spectroscopic data showed that in the samples obtained by precipitation with water after the reaction reached completion, the target products are the major components. For the reaction to reach completion, it was enough to shortly reflux the components in EtOH in the presence of a catalytic amount of CF_3COOH. However, the time of crystallization varied within a wide range. It was accelerated by the addition of seeds and the trituration with a glass rod after cooling the reaction mixture. Compounds **6** have the tendency to form solvates, and the rapid crystallization can indicate the precipitation of a solvate with the solvent. The behavior of compounds **6** with solvents is so individual, that it is impossible to formulate any general principles. For example, compounds **6b** and **6e** fairly well crystallize from nitromethane, to form solvates with one or two CH_3NO_2 molecules, respectively. In the solvate **6a** with acetonitrile, the ratio compound : solvent = 1 : 2.375, whereas in the solvate **6h** with nitromethane, it is 1 : 1.36. These ratios were found in the process of the X-ray diffraction studies. In contrast to the aforementioned substances, compound **6c** is poorly soluble in nitromethane on reflux and does not form stable solvate with it. Most of spiranes **6** form with alcohols strong solvates with a definite stoichiometry. In the work, we report the ^1H NMR spectroscopic and elemental analysis data for such solvates of compounds **6f** and **6h**. At the same time, compound **6g** recrystallized from propanol does not contain the solvent molecule.

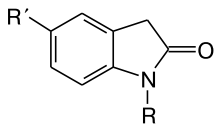
Compounds **6** are stable in acidic media. Thus, the unchanged starting compound was isolated with water from the solution of **6a** in CF_3COOH standing for 1 day at room temperature. Compound **6a** remained unchanged after reflux for several hours in EtOH in the presence of a catalytic amount of CF_3COOH.

The stoichiometry of compounds **6a**,**c—f** was confirmed by their mass spectra. Compound **6g** does not form molecular ion, however, the fragmentation confirms the suggested structure (a Finnigan MATINCOS 50 instrument, direct injection of the sample). Attempted recording of the mass spectrum of **6g** on a Shimadzu GCMS-QP2010 SE GLC-MS spectrometer with the injection of the sample through the chromatograph with a Supelco SLB-5ms column with the injector temperatures of 250—280 °C led to the unexpected result. The compound decomposed in the injector to give two compounds with the molecular weights of 226 and 282, that corresponded to the phenazine **7** and oxindole **8g** derivatives, respectively (Scheme 2).

The fragmentation agrees with these structures. It resulted from the intramolecular oxidation-reduction process with the transfer of two hydrogen atoms of the diazepine fragment to the oxindole one, which was accompanied by the rearrangement of the seven-membered diazepine ring to the six-membered one and the disintegration of spirane **6g** (molecular weight 508) to 3,3-dimethyl-1,2,3,4-tetrahydrophenazin-1-one (**7**) and 5-(morpholinosulfonyl)oxindole (**8g**).

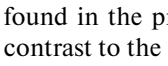
It can be suggested that the enamine form **B** of compound **6g** undergoes the rearrangement, in which both hydrogen atoms to be transferred are in the close proximity to the acceptor, *i.e.*, the electrophilic spirane carbon atom (see Scheme 2).

The reaction has proved to be of general character for compounds **6**. Other spiranes **6** also underwent similar thermal auto-redox rearrangement with disintegration to phenazine **7** and the corresponding oxindole **8** in the instrument injector at $t > 250$ °C.



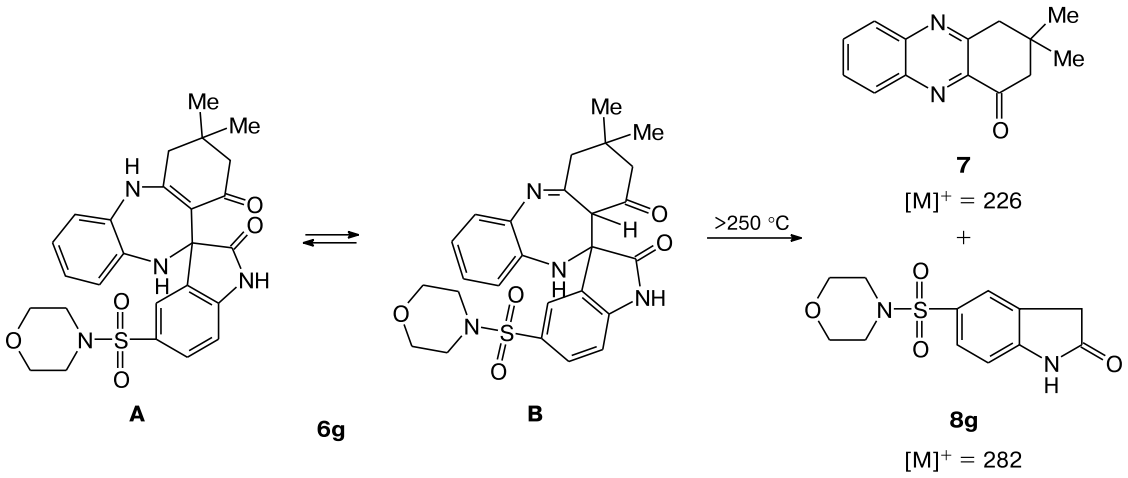
8a—h

R = H, R′ = H (**a**), Me (**b**); MeO (**c**); F (**d**); Cl (**e**); Br (**f**);



(**g**); R = CH_2OH, R′ = H (**h**)

Scheme 2



Taking spirane **6a** as an example, the reaction was carried out on a preparative scale. Phenazine **7** was isolated in 63% yield, whereas the presence of oxindole **8a** in the residue was confirmed by mass spectrometry (Scheme 3).

The molecular weight of compound **6h** is 389, however, the peak of 371 units corresponds to the highest weight in its mass spectrum. This can be explained by the complete decomposition with elimination of H_2O molecule caused by the electron impact. The structure of **6h** was unambiguously confirmed by X-ray diffraction analysis.

All four structurally characterized compounds (**6a**,**d**,**e**,**h**) contain the solvent molecules of acetonitrile or nitromethane, some of which are rather strongly disordered. The symmetrically independent part of the unit cell in the structures **6a** and **6d** contains two molecules (A and A´, respectively). All the molecules have very close structures (Fig. 1).

The indolinone bicycle is bonded to the tricyclic dibenzodiazepine fragment through the spiro-atom C(7). The central diazepine ring is characterized by the distorted and flattened boat conformation, the cyclohexenone fragment has the conformation the intermediate between sofa and chair. The major differences in the structures of the molecules consist in the different degrees of distortion of the conformations indicated. In all the molecules considered, atom N(2) is pyramidal in shape, whereas atom N(3), on the contrary, is planar (Table 1), apparently, because of its involvement in the conjugation in the fragment N(3)—C(15)=C(16)—C(17)=O(2), which is characterized by the flattened structure (the torsional angles deviate from 180° by no more than 12°).

Analysis of crystal packing of compounds under consideration seems to be of the most interest. The experimental data obtained show that compounds **6a**, **6e**, and **6d**, though differing in the substituent in the indolinone bicycle (R = H, Cl, F, respectively) and having different composition of the symmetrically independent part of the unit cell, form similar hydrogen-bonded layers in the crystal structure (Fig. 2, Table 2). The molecules are bound to dimers the strongest due to the interactions N(1)—H(1)...O(2), which form layers due to the interactions N(3)—H(3)...O(1). The dimers are bound between each other by the second order axis. In the structure **6e**, the molecules in the dimer are bound by the center of symmetry, whereas in the structures **6a** and **6d**, the dimer is formed by two symmetrically independent molecules A and A´, which are pseudocentrosymmetric. Note that the group N(2)—H(2) either is

Scheme 3

Table 1. Geometry of nitrogen-containing groups in compounds **6a**, **6e**, **6d**, and **6h**

Compound	$\Sigma\varphi_{N(2)}$ [a]	$\Sigma\varphi_{N(3)}$ [b]
	deg	
6a (A)	329	360
6a (A´)	329	360
6e	334	359
6d (A)	335	360
6d (A´)	332	360
6h	337	359

[a] The sum of angles at atom N(2).
[b] The sum of angles at atom N(3).

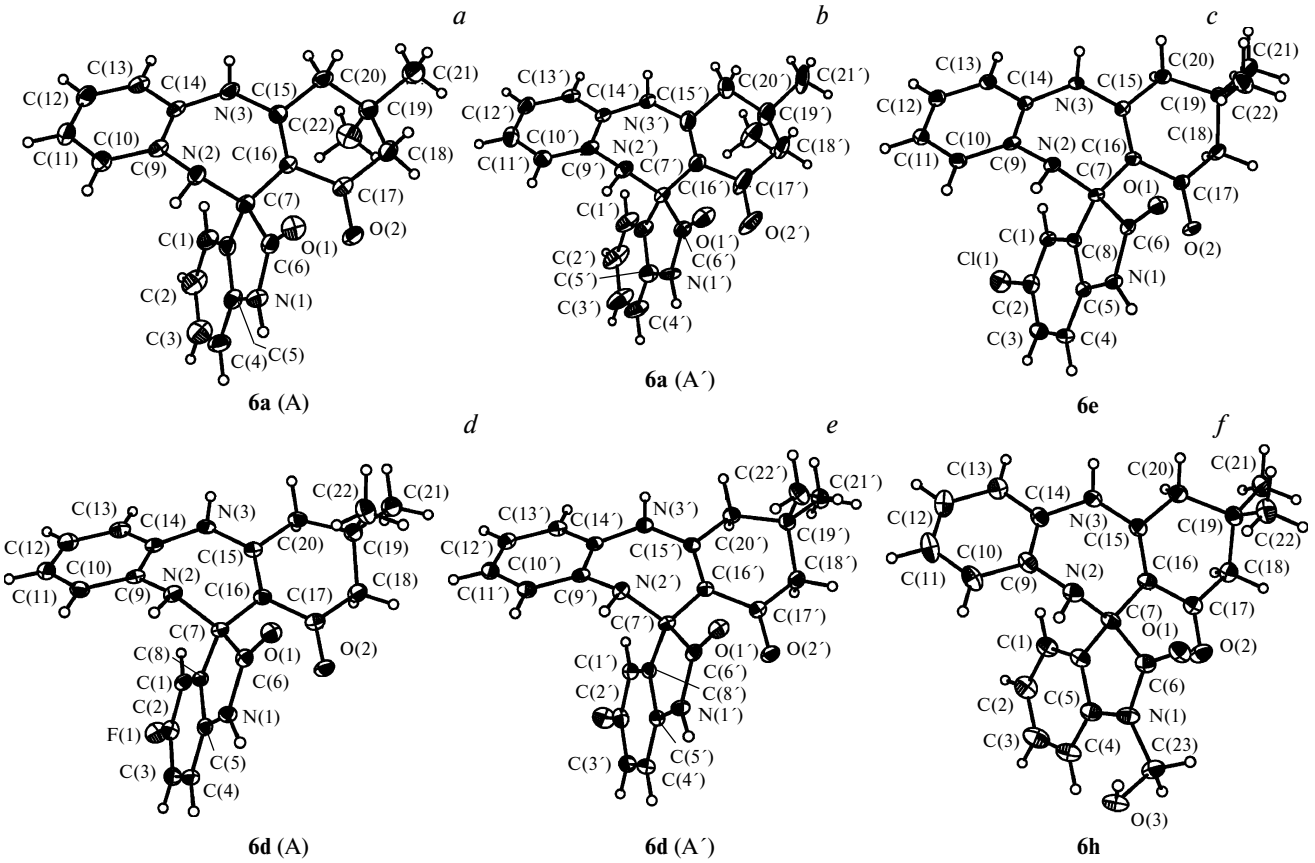


Fig. 1. General view of molecules **6a** (*a*, *b*), **6e** (*c*), **6d** (*d*, *e*), **6h** (*f*) in representation of atoms by the ellipsoids of atomic displacements with 50% probability. For compounds **6a** and **6d**, the structures of two independent molecules A (*a*, *c*) and A´ (*b*, *d*) are given.

Table 2. Geometry of hydrogen bonds in the crystal structures of **6a**, **6e**, **6d**, and **6h**

Compound	H-bond	*d*(H...O)	*d*(N...O)	N—H...O /deg
		Å		
6a	N(1)—H(1)...O(2´)	1.95	2.826(3)	165
	N(2)—H(2)...N(1S)	2.22	3.109(4)	173
	N(3)—H(3)...O(1)[a]	1.97	2.851(3)	167
	N(1´)—H(1´)...O(2)	1.91	2.799(3)	170
	N(3´)—H(3´)...O(1´)[b]	1.97	2.848(3)	166
6e	N(1)—H(1)...O(2´)[c]	1.96	2.860(2)	175
	N(2)—H(2)...O(2S)	2.40	3.288(2)	170
	N(3)—H(3)...O(1)[d]	2.12	2.971(2)	158
6d	N(1)—H(1)...O(2´)	1.95	2.839(2)	170
	N(3)—H(3)...O(1)[e]	1.98	2.864(2)	168
	N(1´)—H(1´)...O(2)	1.99	2.881(2)	171
	N(3´)—H(3´)...O(1´)[f]	1.98	2.843(2)	161
6h	O(3)—H(1)...N(2)[g]	1.98	2.807(2)	163
	N(2)—H(2)...O(1)[g]	2.10	2.985(2)	168
	N(3)—H(3)...O(3)[h]	2.06	2.950(2)	172

[a] $1.5 - x, y - 0.5, 0.5 - z$. [b] $0.5 - x, y + 0.5, 0.5 - z$.
[c] $1 - x, 2 - y, -z$. [d] $1.5 - x, y - 0.5, 0.5 - z$.
[e] $1.5 - x, y - 0.5, 0.5 - z$. [f] $0.5 - x, y + 0.5, 0.5 - z$.
[g] $2 - x, -y, 2 - z$. [h] $x - 1, y, z$.

not involved in the H-bonding or forms a weak H-bond with the solvent molecules. To sum up, in compounds **6a**, **6e**, **6d**, the interactions of groups N(1)—H(1) and N(3)—H(3) with the carbonyl oxygen atoms O(1) and O(2) lead to the formation of the stable enough motif, despite the fact that such a mutual arrangement of molecules leads to the formation of cavities, which, in turn, explains the presence of solvent molecules in the structures.

The structure **6h** differs from the molecules considered above by the replacement of the group N(1)—H(1) with N(1)—CH_2—OH, that leads to a dramatic change in the system of hydrogen bonds in the crystal structure, despite the similarity of the molecular structures, as it was mentioned above. In this case, the group N(2)—H(2) is not practically involved in the H-bonding of compounds **6a**, **6e**, and **6d**. In the case of **6h**, the group N(1)—CH_2—OH is simultaneously involved as both the proton donor and the proton acceptor. The molecules are combined in the centrosymmetric dimers by the bonds N(2)—H(2)...O(1) and O(3)—H(1)...N(2), the dimers form chains due to the bonds N(3)—H(3)...O(3), whereas O(2) atom of the carbonyl group is not involved in the system of H-bonds (Fig. 3).

To sum up, the stable enough motif of the crystal packing formed by the strongest proton-donor and proton-

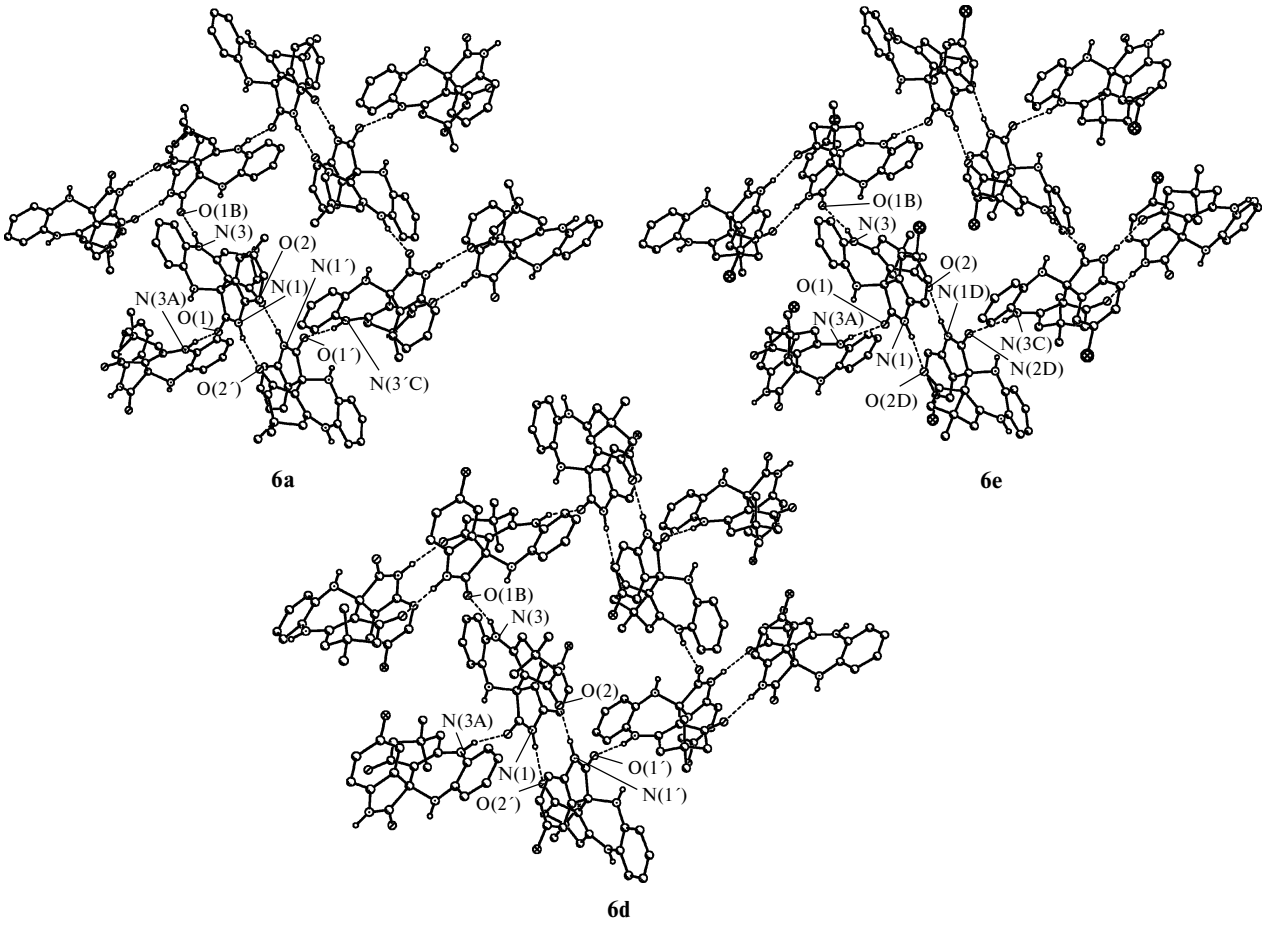


Fig. 2. Fragments of H-bonded layers in the crystal structures of compounds **6a**, **6e**, and **6d**.

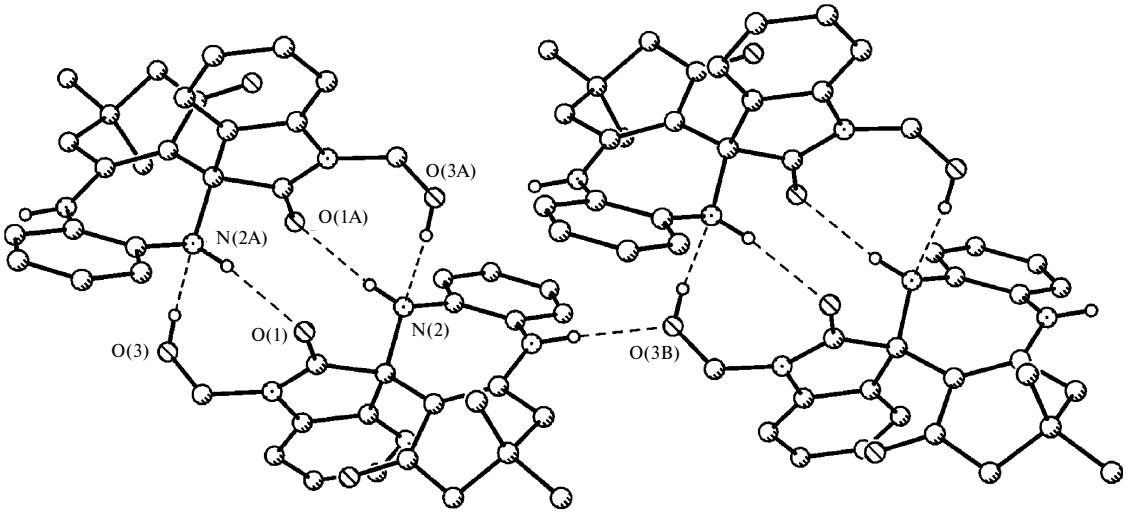


Fig. 3. Fragment of the H-bonded chain in the crystal structure of **6h**.

acceptor groups in compounds **6a**, **6e**, and **6d** completely changes upon the replacement of the fragment NH with the fragment N—CH_2OH, and in this case, the strongest donors of protons (the N(3)—H(3) group and the hydroxy group) form hydrogen bonds with relatively weak acceptors of protons (atoms N(2), O(3)), whereas one of the

most efficient proton acceptors (atom O(2)) is not involved in the H-bonding.

In conclusion, note that the circle of representatives of this new heterocyclic spiro system can be considerably extended by the involvement in the synthesis of analogs of compound **4**. The latter can be obtained from the C-substituted derivatives of *o*-phenylenediamine, as well as from other aromatic and heteroaromatic diamines in the reactions with dimedone and other cyclic β-diketones. The use of such complex, functionally substituted spiranes **6** in the thermal rearrangement described in the present work with the purpose of preparative synthesis of its products should not be excluded either.

Experimental

IR spectra were recorded on a Varian Excalibur 3100 FT-IR spectrometer using FTIR method. ^{1}H NMR spectra were recorded on a Varian UNITY-300 spectrometer. Mass spectra were obtained on a Finnigan MAT INCOS 50 instrument with direct injection of the samples (EI, ionization energy 70 eV).

Experiments on the thermal rearrangement of compounds **6** were carried out on a Shimadzu GCMS-QP2010 SE GLC-MS spectrometer with injection of the samples through a Supelco SLB-5 ms chromatographic column, injector temperature 280 °C.

Compound **4** was synthesized according to the procedure described in the work.[10] Commercial samples of isatines **5a**—**f** were used in the syntheses. References for the preparation of isatines **5g**,**h** are given in the descriptions of the experiments.

Synthesis of spirooxindolodibenzodiazepines (general procedure). An equimolar mixture of compounds **4** and **5** (1—2 mmol of each) was dissolved in EtOH upon reflux, followed by the addition of several drops of CF_3COOH, then the mixture was allowed to stand at room temperature for several hours. The reaction proceeded rapidly. In some cases, crystallization began within first 10 min, in others only after several hours of standing. A reaction product could be precipitated with water.

3,3-Dimethyl-2,3,4,5,10,11-hexahydrospiro[1*H*-dibenzo-[*b*,*e*][1,4]diazepine-11,3′-2*H*-indole]-1,2′-dione (6a). A mixture of **4** (0.46 g, 2 mmol) and **5a** (0.3 g, 2 mmol) in EtOH (10 mL) with two drops of CF_3COOH was heated to boiling and allowed to stand for 3 h. Trituration with a glass rod was used, after 2 h the mixture was placed on ice and after another 1 h filtered, washed with cold EtOH and light petroleum, and dried at 100 °C. The yield of **6a** was 0.36 g (50%). Colorless compound with m.p. 203—207 °C (from EtOH). Additional amount of the product (0.29 g) was precipitated from the filtrate with water, which had practically identical IR spectrum. The structure was confirmed by X-ray crystallography. IR, ν/cm^{-1}: 3298, 3237, 3188 (NH), 1712 (CO); 1616, 1599, 1518, 1506 (arom.). ^{1}H NMR (DMSO-d_6), δ: 1.02, 1.15 (both s, 6 H, CH_3); 1.88, 2.06 (both d, 2 H, CH_2, J = 16.2 Hz); 2.54, 2.64 (both d, 2 H, CH_2, J = 16.2 Hz); 5.14 (s, 1 H, NH); 6.21 (d, 1 H, CH_{arom}, J = 7.2 Hz); 6.50 (t, 1 H, CH_{arom}, J = 7.5 Hz); 6.62—6.84 (m, 3 H, CH_{arom}); 6.96 (t, 1 H, CH_{arom}, J = 7.5 Hz); 7.08 (d, 1 H, CH_{arom}, J = 7.8 Hz); 8.88 (s, 1 H, NH); 10.07 (s, 1 H, NH). MS, m/z: 359 $[M]^+$. At 280 °C, compound **6a** disintegrates to two compounds, *viz.*, phenazine **7** and oxindole **8a**, m/z 133 $[M]^+$.

3,3,5′-Trimethyl-2,3,4,5,10,11-hexahydrospiro[1*H*-dibenzo-[*b*,*e*][1,4]diazepine-11,3′-2*H*-indole]-1,2′-dione (6b). A mixture of **4** (0.23 g, 1 mmol) and **5b** (0.16 g, 1 mmol) was refluxed in EtOH (4 mL) until dissolution, 1 drop of CF_3COOH was added. The mixture was heated to the boiling point, allowed to stand for 1 h, and poured into cold water (20 mL). A precipitate formed was filtered off, washed with H_2O, and dried. The yield of crude product was 0.33 g (88%); m.p. 197—200 °C (from MeCN). The product was recrystallized from MeCN and dried at 100 °C. Found (%): C, 73.61; H, 6.49. $C_{23}H_{23}N_3O_2$. Calculated (%): C, 73.97; H, 6.21. IR, ν/cm^{-1}: 3305, 3234, 3148 (NH); 1686 (CO); 1609, 1583, 1535 (arom.). ^{1}H NMR (DMSO-d_6), δ: 1.04, 1.15 (both s, 6 H, CH_3); 1.88, 2.03 (both d, 2 H, CH_2, J = 16.2 Hz); 2.55, 2.62 (both d, 2 H, CH_2, J = 16.5 Hz); 5.07 (s, 1 H, NH); 6.01 (s, 1 H, CH_{arom}); 6.50—6.95 (m, 5 H, CH_{arom}); 7.07 (d, 1 H, CH_{arom}, J = 8.1 Hz); 8.87 (s, 1 H, NH); 9.96 (s, 1 H, NH). At 280 °C, disintegrates to two compounds, *viz.*, phenazine **7** and oxindole **8b**, m/z 147 $[M]^+$.

5′-Methoxy-3,3-dimethyl-2,3,4,5,10,11-hexahydrospiro-[1*H*-dibenzo[*b*,*e*][1,4]diazepine-11,3′-2*H*-indole]-1,2′-dione (6c) was obtained from **4** (0.23 g, 1 mmol) and **5c** (0.18 g, 1 mmol) in EtOH (4 mL) with one drop of CF_3COOH. After 2 h, a plentiful light precipitate was formed from a dark solution, which was filtered off, washed with cold EtOH and light petroleum, and dried at 100 °C. The yield was 0.254 g (65%). Colorless compound, poorly soluble in boiling $MeNO_2$; m.p. 238—241 °C (from $MeNO_2$). Found (%): C, 70.75; H, 6.23. $C_{23}H_{23}N_3O_3$. Calculated (%): C, 70.93; H, 5.95. IR, ν/cm^{-1}: 3298, 3249, 3200 (NH); 1713 (CO); 1604, 1583, 1536, 1491 (arom.). ^{1}H NMR (DMSO-d_6), δ: 0.96, 1.08 (both s, 6 H, CH_3); 1.88, 2.01 (both d, 2 H, CH_2, J = 16.2 Hz); 2.56, 2.62 (both d, 2 H, CH_2, J = 16.8 Hz); 3.40 (s, 3 H, OCH_3); 5.42 (s, 1 H, NH); 5.76 (d, 1 H, C(1)H, J = 2.4 Hz); 6.56 (dd, 1 H, C(3)H, ^3J = 8.4 Hz, ^4J = 2.4 Hz); 6.63 (m, 2 H, CH_{arom}); 6.74 (t, 1 H, CH_{arom}, J = 7.5 Hz); 6.84 (t, 1 H, CH_{arom}, J = 7.5 Hz); 7.11 (d, 1 H, CH_{arom}, J = 7.8 Hz); 9.02 (s, 1 H, NH); 9.97 (s, 1 H, NH). MS, m/z: 389 $[M]^+$. At 280 °C, disintegrates to two compounds, *viz.*, phenazine **7** and oxindole **8c**, m/z 163 $[M]^+$.

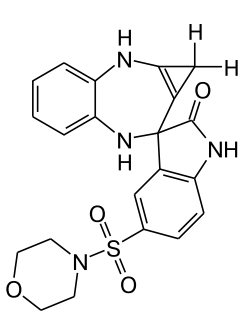
5′-Fluoro-3,3-dimethyl-2,3,4,5,10,11-hexahydrospiro[1*H*-dibenzo[*b*,*e*][1,4]diazepine-11,3′-2*H*-indole]-1,2′-dione (6d) was obtained from **4** (0.23 g, 1 mmol) and **5d** (0.165 g, 1 mmol) in EtOH (4 mL) with one drop of CF_3COOH. After 2 h, the mixture was cooled on ice, triturating with a rod. A precipitate formed was filtered off, washed with light petroleum, and dried. The yield was 0.244 g (65%). Colorless compound, m.p. 200—205 °C. Crystallized from CH_3NO_2 as a solvate with CH_3NO_2, whose structure was confirmed by X-ray crystallography. IR, ν/cm^{-1}: 3293, 3242, 3197 (NH); 1711 (CO); 1627, 1601, 1587, 1509, 1491, 1482 (arom.). ^{1}H NMR of the solvate **6d** with CH_3NO_2 (DMSO-d_6), δ: 0.96, 1.08 (both s, 6 H, CH_3); 1.89, 2.00 (both d, 2 H, CH_2, J = 15.9 Hz); 2.59 (s, 2 H, CH_2); 4.41 (s, 3 H, CH_3NO_2); 5.54 (s, 1 H, NH); 5.89 (dd, 1 H, CH_{arom}, ^3J = 8.1 Hz, ^4J = 2.4 Hz); 6.50—7.00 (m, 5 H, CH_{arom}); 7.12 (d, 1 H, CH_{arom}, J = 7.8 Hz); 9.08 (s, 1 H, NH); 10.17 (s, 1 H, NH). MS, m/z: 377 $[M]^+$. At 280 °C, disintegrates to two compounds, *viz.*, phenazine **7** and oxindole **8d**, m/z 151 $[M]^+$.

5′-Chloro-3,3-dimethyl-2,3,4,5,10,11-hexahydrospiro[1*H*-dibenzo[*b*,*e*][1,4]diazepine-11,3′-2*H*-indole]-1,2′-dione (6e) was obtained from **4** (0.23 g, 1 mmol) and **5e** (0.18 g, 1 mmol) in EtOH (8 mL) with one drop of CF_3COOH. After 2 h, the reac-

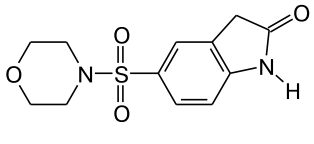
tion mixture with a precipitate was cooled on ice. The precipitate was filtered off, washed with cold EtOH and light petroleum, and dried. The yield was 0.33 g (84%). Colorless compound, m.p. 207—210 °C. Crystallized from CH_3NO_2 as a solvate with CH_3NO_2, whose structure was confirmed by X-ray crystallography. IR, ν/cm^{-1}: 3304, 3240, 3150 (NH); 1717 (CO); 1604, 1583, 1534, 1506, 1493, 1475 (arom.). ^{1}H NMR (DMSO-d_6), δ: 0.97, 1.08 (both s, 6 H, CH_3); 1.91, 2.00 (both d, 2 H, CH_2, J = 16.0 Hz); 2.60 (s, 2 H, CH_2); 5.57 (s, 1 H, NH); 6.08 (d, 1 H, CH_{arom}, J = 2.4 Hz); 6.65 (dd, 1 H, CH_{arom}, ^3J = 7.8 Hz, ^4J = 1.5 Hz); 6.74 (m, 2 H, CH_{arom}); 6.87 (tt, 1 H, CH_{arom}, ^3J = 7.5 Hz, ^4J = 1.5 Hz); 7.05 (dd, 1 H, CH_{arom}, ^3J = 8.1 Hz, ^4J = 2.1 Hz), 7.14 (dd, 1 H, CH_{arom}, ^3J = 8.1 Hz, ^4J = 1.5 Hz); 9.09 (s, 1 H, NH); 10.29 (s, 1 H, NH). MS, *m/z*: 393 $[M]^+$. At 280 °C, disintegrates to two compounds, *viz.*, phenazine **7** and oxindole **8e**, *m/z* 167 $[M]^+$.

5´-Bromo-3,3-dimethyl-2,3,4,5,10,11-hexahydrospiro[1*H*-dibenzo[*b*,*e*][1,4]diazepine-11,3´-2*H*-indole]-1,2´-dione (6f). A mixture of **4** (0.46 g, 2 mmol) and **5f** (0.45 g, 2 mmol) in EtOH (10 mL) was heated to boiling point, two drops of CF_3COOH was added, and reflux was continued until dissolution (1—2 min). After cooling to room temperature (~15 min), the mixture was treated with water, a precipitate formed was filtered off, washed with water, and dried. The yield of crude product was 0.7 g (80%), m.p. 205—212 °C (from EtOH). For elemental analysis and spectroscopic studies, the product was recrystallized from EtOH, with which it formed a solvate 1 : 1. Found (%): C, 59.16; H, 6.03; Br, 16.22. $C_{24}H_{26}N_3O_3Br$. Calculated (%): C, 59.51; H, 5.41; Br, 16.50. IR, ν/cm^{-1}: 3285, 3244, 3197 (NH); 1721, 1699 (CO); 1614, 1602, 1586, 1508, 1492, 1471 (arom.). ^{1}H NMR (DMSO-d_6), δ: 0.97 (s, 3 H, CH_3); 1.05 (t, 3 H, CH_3, J = 6.9 Hz); 1.09 (s, 3 H, CH_3); 1.92, 2.00 (both d, 2 H, CH_2, J = 16.2 Hz); 2.60 (s, 2 H, CH_2); 3.43 (m, 2 H, CH_2); 4.36 (t, 1 H, OH, J = 5.1 Hz); 5.57 (s, 1 H, NH); 6.20 (d, 1 H, C(1)H, J = 1.8 Hz); 6.65 (t, 1 H, CH_{arom}, J = 7.5 Hz); 6.70 (d, 1 H, CH_{arom}, J = 8.4 Hz). MS, *m/z*: 493 $[M]^+$.

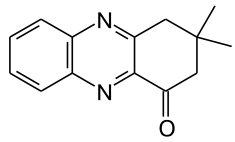
3,3-Dimethyl-5´-morpholinosulfonyl-2,3,4,5,10,11-hexahydrospiro[1*H*-dibenzo[*b*,*e*][1,4]diazepine-11,3´-2*H*-indole]-1,2´-dione (6g). A mixture of **4** (0.23 g, 1 mmol) and **5g** (0.3 g, 1 mmol) (see Ref. 11) was dissolved with reflux in EtOH (20 mL), hot filtered through a dense filter, one drop of CF_3COOH was added, heated to the boiling point, and left to stand for 12 h. A precipitate formed was filtered off, washed with cold EtOH, and dried. The yield of crude product was 0.32 g (63%). After recrystallization from PrOH (25 mL), 0.17 g (33%) of chemically pure compound was obtained. Colorless compound with m.p. 244—245 °C. Found (%): C, 61.22; H, 5.25; S, 6.10. $C_{26}H_{28}N_4O_5S$. Calculated (%): C, 61.40; H, 5.55; S, 6.30. IR, ν/cm^{-1}: 3365, 3287, 3231 (NH); 1736 (CO); 1614, 1595, 1584, 1502 (arom.); 1348, 1155 (SO_2). ^{1}H NMR (DMSO-d_6), δ: 0.94, 1.10 (both s, 6 H, CH_3); 1.93, 2.03 (both d, 2 H, CH_2, J = 16.2 Hz); 2.31 (m, 4 H, CH_2N); 2.63 (s, 2 H, CH_2); 3.50 (m, 4 H, CH_2O); 5.78 (s, 1 H, NH); 6.45 (d, 1 H, CH_{arom}, J = 1.5 Hz); 6.66 (m, 1 H, CH_{arom}); 6.73 (t, 1 H, CH_{arom}, J = 7.5 Hz); 6.88 (t, 1 H, CH_{arom}, J = 7.5 Hz); 6.97 (d, 1 H, CH_{arom}, J = 8.1 Hz); 7.15 (d, 1 H, CH_{arom}, J = 8.1 Hz); 7.41 (dd, 1 H, CH_{arom}, ^3J = 8.1 Hz, ^4J = 1.8 Hz); 9.19 (s, 1 H, NH); 10.73 (s, 1 H, NH). MS (*m/z*): the compound did not give molecular ion, however, the fragmentation confirmed the suggested structure:



424 (str.)



282 (mid.)



226 (str.)

1´-Hydroxymethyl-3,3-dimethyl-2,3,4,5,10,11-hexahydrospiro[1*H*-dibenzo[*b*,*e*][1,4]diazepine-11,3´-2*H*-indole]-1,2´-dione (6h). A mixture of **4** (0.23 g, 1 mmol) and **5h** (0.18 g, 1 mmol) (see Ref. 12) was dissolved with reflux in EtOH (5 mL), followed by the addition of one drop of CF_3COOH. After ~1 h, a crystalline precipitate (a solvate with EtOH 1 : 1) began to form. After trituration with a glass rod and cooling on ice, the precipitate was filtered off, washed with cold EtOH and light petroleum, and dried. The yield was 0.16 g (37%). After recrystallization from PrOH (25 mL), 0.13 g (33%) of compound **6h** was obtained, m.p. 230—240 °C. IR, ν/cm^{-1}: 3293, 3249, 3146 (OH, NH); 1717 (CO); 1607, 1585, 1540, 1511 (arom.). ^{1}H NMR (DMSO-d_6), δ: 0.95, 1.08 (both s, 6 H, CH_3); 1.87, 2.00 (both d, 2 H, CH_2, J = 15.9 Hz); 2.57, 2.64 (both d, 2 H, CH_2, J = 15.9 Hz); 5.03, 5.13 (both d, 2 H, CH_2, J = 10.5 Hz); 5.31 (s, 1 H, NH); 5.95 (br.s, 1 H, OH); 6.21 (d, 1 H, CH_{arom}, J = 7.2 Hz); 6.54 (d, 1 H, CH_{arom}, J = 7.8 Hz); 6.63 (t, 1 H, CH_{arom}, J = 7.2 Hz); 6.73 (t, 1 H, CH_{arom}, J = 7.5 Hz); 6.86 (t, 1 H, CH_{arom}, J = 7.5 Hz); 6.90—7.20 (m, 3 H, CH_{arom}); 9.10 (s, 1 H, NH). MS (*m/z*): the compound did not produce molecular ion, giving upon electron impact a fragment with the mass of 371 and water.

The structure of **6h** was confirmed by X-ray diffraction analysis.

Thermal auto-redox rearrangement of 6a. Compound **6a** (0.3 g, 0.84 mmol) was heated at 250 °C until it completely melted. The dark brown melt was dissolved with heating in $CHCl_3$ and subjected to column chromatography on Al_2O_3 (eluent $CHCl_3$), collecting the head yellow fraction. The solvent was evaporated, the residue was triturated with light petroleum to obtain phenazine **7** (0.12 g, 63%). Yellow compound with m.p. 172—174 °C (from acetone) (*cf.* Ref. 13: m.p. 172—175 °C). MS: *m/z* = 226. The solvent was evaporated from the second fraction (eluent $CHCl_3$: EtOH, 9 : 1), the oily residue was triturated with light petroleum to obtain a solid compound (0.084 g), in which the presence of oxindole **8a** was detected by mass spectrometry: *m/z* = 133.

X-ray diffraction studies of compounds 6a, 6b, 6d, and 6h. Single crystals of compound **6a** suitable for X-ray diffraction experiment were obtained by slow evaporation of the solution in CH_3CN, or solutions in CH_3NO_2 were used to grow crystals of compounds **6b**,**d**,**h**. The experimental intensities of reflections were measured on a SMART APEX2 CCD diffractometer (λ(Mo-Kα) = 0.71073 Å, graphite monochromator, ω-scan technique) at 100 K. The starting massifs of measured intensities were processed using the SAINT and SADABS programs included into the APEX2 software.[14] The structures were solved by direct method and refined by the full-matrix least squares meth-

Table 3. Crystalographic data and parameters of X-ray diffraction experiment for compounds **6a**, **6e**, **6d**, and **6h**

Parameter	**6a**	**6e**	**6d**	**6h**
Molecular formula	$C_{22}H_{21}N_3O_2 \cdot 2.375C_2H_3N$	$C_{22}H_{20}ClN_3O_2 \cdot 2CH_3NO_2$	$C_{22}H_{20}FN_3O_2 \cdot CH_3NO_2$	$C_{23}H_{23}N_3O_3 \cdot 1.36CH_3NO_2$
Molecular weight	456.92	515.95	438.45	472.46
Crystal color	Bright yellow	Bright yellow	Bright yellow	Bright yellow
Crystal form	Plates	Plates	Prisms	Needles
Crystal size/mm	0.21×0.17×0.02	0.26×0.23×0.04	0.26×0.22×0.16	0.17×0.03×0.02
Crystal system	Monoclinic	Monoclinic	Monoclinic	Monoclinic
Space group	$P2_1/n$	$P2_1/n$	$P2_1/n$	$P2_1/c$
a/Å	19.545(4)	12.1667(16)	18.4759(10)	10.5411(8)
b/Å	11.812(2)	11.2698(15)	11.9740(6)	15.4198(12)
c/Å	22.704(4)	19.113(2)	20.4035(11)	14.2520(11)
β/deg	110.811(3)	106.712(3)	105.2410(10)	94.647(2)
V/Å^3	4899.4(15)	2510.1(6)	4355.1(4)	2308.9(3)
Z	8	4	8	4
d_{calc}/g cm^{-3}	1.239	1.365	1.337	1.359
Absorption coefficient μ/mm^{-1}	0.081	0.201	0.099	0.098
F(000)	1938	1080	1840	998
Intensity of scaning on θ/deg	1.92—28.00	1.78—29.00	1.99—28.00	1.94—30.00
Number of measured reflections	53098	29218	47342	30265
Number of independent reflections	11824	6664	10467	6727
R_{int}	0.0436	0.0389	0.0705	0.0377
Number of refined parameters	601	292	602	264
Number of reflection with $I \geq 2\sigma(I)$	5275	4605	6611	3610
Completeness of reflection massif (%)	99.8	99.8	99.6	99.9
GOOF	0.960	1.040	1.031	0.983
Refinement convergence ($R_1(F)$)[a] on reflections with $I \geq 2\sigma(I)$	0.0796	0.0542	0.0499	0.0661
Refinement convergence on all the reflections ($wR_2(F^2)$[b]	0.2050	0.1332	0.1406	0.1538
Residual max/min, e/Å^3	0.454/−0.381	0.496/−0.441	0.437/−0.326	0.337/−0.256

[a] $R_1 = \Sigma||F_o| - |F_c||/\Sigma(F_o)$. [b] $wR_2 = (\Sigma[w(F_o^2 - F_c^2)^2]/\Sigma[w(F_o^2)^2]^{1/2}$.

od in anisotropic approximation for nonhydrogen atoms on F^2_{hkl}. The solution and refinement of structures were carried out using the SHELXTL program.[15] The principal crystallographic data and parameters of X-ray diffraction experiments are given in Table 3. The atom coordinates and the temperature factors, as well as the details of the refinement of the solvent molecules were deposited with the Cambridge Structural Database (http://www.ccdc.cam.ac.uk/products/csd/request/, CCDC 912574—912577 for **6a**, **6e**, **6b,** and **6h**, respectively).

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Received January 17, 2013;
in revised form March 15, 2013