DOI 10.1007/s10593-015-1676-7

Chemistry of Heterocyclic Compounds **2015**, *51*(2), 166–169

On the reactivity of benzo[*a*]phenazine-5,6-dione 7-oxides with methanolic alkali and pyrrolidine

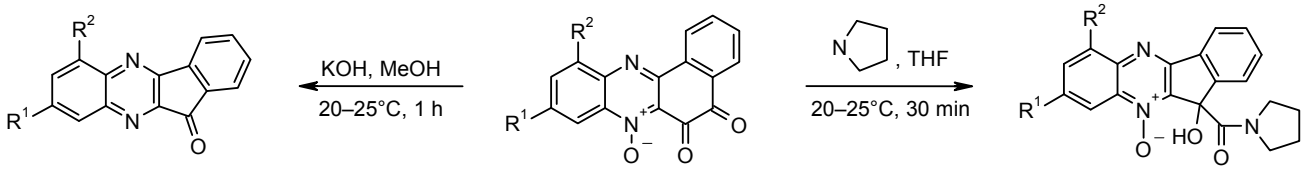
Leonid M. Gornostaev[1]*, Tatyana A. Rukovets[2], Elena V. Arnold[1], Tatyana I. Lavrikova[1], Juliya G. Khalyavina[1], Irina S. Kryukovskaya[2]

[1] *Krasnoyarsk State Pedagogical University named after V. P. Astaf'ev, 89 A. Lebedeva St., Krasnoyarsk 660049, Russia; e-mail: gornostaev@kspu.ru*

[2] *Krasnoyarsk State Medical University named after Professor V.F. Voyno-Yasenetsky, 1 Partizan Zheleznyak St., Krasnoyarsk 660021, Russia; e-mail: tatyana_xim@mail.ru*

Translated from Khimiya Geterotsiklicheskikh Soedinenii, 2015, *51*(2), 166–169

Submitted December 31, 2014
Accepted January 19, 2015



When treated with methanolic alkali, benzo[*a*]phenazine-5,6-dione 7-oxides convert into 11*H*-indeno[1,2-*b*]quinoxalin-11-ones, whereas 11-hydroxy-11-(pyrrolidine-1-carbonyl)-11*H*-indeno[1,2-*b*]quinoxaline 10-oxides form upon treatment with pyrrolidine.

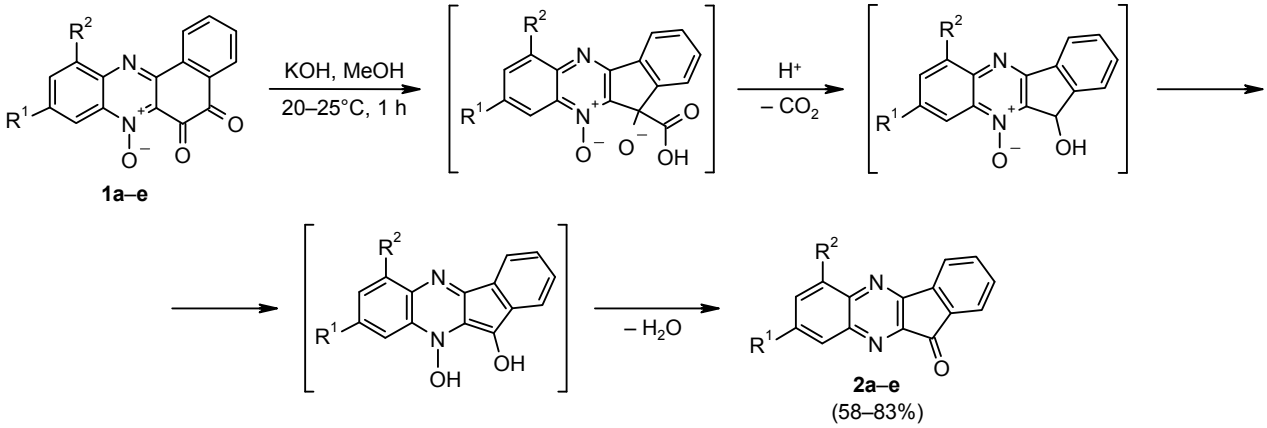
Keywords: benzo[*a*]phenazine-5,6-dione 7-oxides, 11*H*-indeno[1,2-*b*]quinoxalin-11-ones, benzilic acid rearrangement.

Phenazine *N*-oxides and dioxides attract the attention of researchers as substances exhibiting a range of biological activities. It is known that phenazine *N*-oxide possesses antibacterial activity[1], and its hydroxyl and amide derivatives exhibit antitumor activity[2,3]. Also, phenazine 5,10-dioxides were recently identified as prodrugs for antitumor therapy due to cytotoxic properties.[4,5] Study of the chemical properties of phenazine *N*-oxides, therefore, is of interest.

We have found that benzo[*a*]phenazine-5,6-dione 7-oxides **1a**–**e** are converted into 11*H*-indeno[1,2-*b*]-quinoxalin-11-ones **2a**–**e** when treated with methanolic potassium hydroxide solution at 20-25°C. The reaction is accompanied by the release of CO_2, contraction of the *ortho*-quinoid ring, and deoxygenation of the *N*-oxide fragment (Scheme 1).

The structure of 11*H*-indeno[1,2-*b*]quinoxalin-11-ones **2a-e**, currently studied in view of their antimicrobial,

Scheme 1

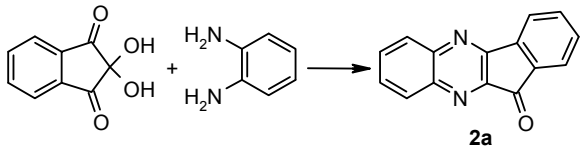


1, **2 a–d** R^2 = H, **a**,**e** R^1 = H, **b** R^1 = Me, **c** R^1 = Cl, **d** R^1 = F, **e** R^2 = Me

antihypertensive, antituberculosis, antimalaria, anti-inflammatory, anticonvulsant, antiHIV, and anticancer activity,[6-8] was verified by counter synthesis of compound **2a** from ninhydrin and 1,2-diaminobenzene[9,10] (Scheme 2).

Characteristically, the signals of the quinonoid carbon atoms in the ^{13}C NMR spectra of benzo[*a*]phenazine-5,6-dione 7-oxides **1a–e** are in the 171-178-ppm range, while the

Scheme 2



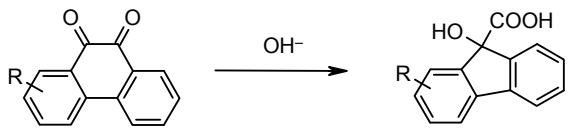
2a

signal of the single carbonyl carbon atom in ^{13}C NMR spectra of 11*H*-indeno[1,2-*b*]quinoxalin-11-ones **2a–e** is at ~190 ppm, which correlates with literature data.[11] Our attempts to isolate any of the intermediates in the reaction **1→2** were unsuccessful. When phenazine *N*-oxides **1a–e** were treated with methanolic KOH at low temperature (0–5°C), as well as treating them with potassium phenoxide in dioxane (at 15–20°C), only the corresponding quinoxalines **2a–e** are formed.

The reaction **1→2** differs from classical cases of benzilic acid rearrangement of *ortho*-quinonoid polycyclic compounds such as phenanthrenequinone **3**[12] reaction with alkalis where the main products are derivatives of 9-hydroxyfluorene-9-carboxylic acid **4** (Scheme 3).

Notably, the rearrangement of phenanthrenequinones into 9-hydroxyfluorene-9-carboxylic acids is greatly facilitated by electron-withdrawing substituents in the benzenoid fragment of phenanthrenequinone. Thus, unsubstituted phenanthrenequinone isomerizes to the corresponding hydroxyfluorenecarboxylic acid under prolonged heating at 80°C, 2- and 4-mononitro-

Scheme 3



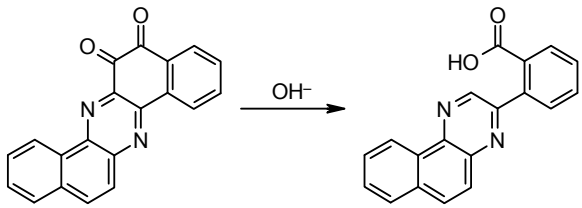
3 R = H, Br, NO_2 **4**

phenanthrenequinones at 65°C, whereas 2,7- and 4,5-dinitrophenanthrenequinones at 15°C.

Dibenzophenazinedione **5**, a closer related analog of benzo[*a*]phenazine-5,6-dione 7-oxides, transforms in low yield into 2-quinoxalylbenzoic acid **6** only when boiled with concentrated aqueous NaOH[13] (Scheme 4).

Therefore, the presence of an *N*-oxide fragment in phenazinedione derivatives **1a–e** enhances their reactivity towards and selectivity in the electrophilic reaction with alkalis. Increased electrophilic reactivity of phenazinedione *N*-oxides is also confirmed by the reaction of compounds **1a**,**b**,**e** with pyrrolidine, resulting in 11-hydroxy-11-(pyrrolidin-1-ylcarbonyl)-11*H*-indeno[1,2-*b*]quinoxaline 10-oxides **7a–c** with preservation of the *N*-oxide moiety (Scheme 5). The structure and composition of compounds **7a–c** were confirmed by physicochemical analysis. It should be noted that data on amine-induced cleavage of

Scheme 4

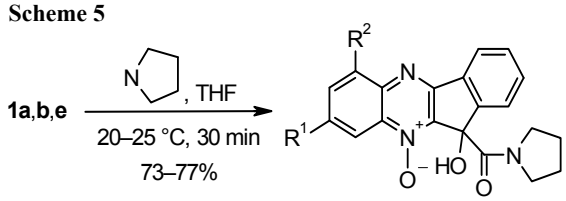


5 **6**

phenanthrenequinones and their diaza-analogs is absent in the literature.

To conclude, we have found unique reactions of benzo[*a*]-phenazine-5,6-dione 7-oxides, with their direction explained by structural features of the starting materials, namely, the presence of *N*-oxide moiety in their molecules.

Scheme 5



7a,**b**,**c**

7 a $R^1 = R^2 = H$; **b** $R^1 = Me$, $R^2 = H$; **c** $R^1 = H$, $R^2 = Me$

Experimental

IR spectra were registered on a Shimadzu IRAffinity-1 spectrometer in KBr pellets. UV spectra were recorded on an Evolution 300 (10-mm cuvettes) spectrophotometer in acetonitrile. ^1H and ^{13}C NMR spectra were acquired on a Bruker DRX spectrometer (500 and 125MHz, respectively) in DMSO-d_6 (compounds **1e**, **2a–e**) or $CDCl_3$ (compounds **7a–c**), with TMS as internal standard. Chemical shifts of ^{13}C nuclei were assigned using published data.[11] Mass spectra were recorded on a Finnigan MAT 8200 (EI ionization, 70 eV) mass spectrometer. High-resolution mass spectra for compounds **1e** and **2e** were recorded on a Thermo Scientific DFS (direct injection, EI ionization, 70 eV), whereas for compounds 7**b**,**c** they were acquired on a Bruker microOTOF II mass spectrometer with electrospray ionization in positive-ion mode (voltage applied to capillary 4500 V).[14] Scanned mass range *m*/*z* 50–3000. Direct infusion of acetonitrile solution of samples by syringe pump was used, flow rate 3 ml/min. Nitrogen nebulizing gas (4 l/min), interface temperature 180°C. Elemental analysis was performed on a EURO EA 3000 Elemental Analyzer. Melting points were determined on a Boetius heating bench. Monitoring of the reaction progress and assessment of the purity of synthesized compounds was done by TLC on Silufol UV-254 plates (eluent: toluene–acetone, 10:1).

The starting benzo[*a*]phenazine-5,6-dione 7-oxides **1a–d** were prepared according to published procedures,[15] while oxide **1e** was prepared analogously. 4-(*o*-Tolylamino)-1,2-naphthoquinone was synthesized following a published method.[16]

11-Methyl-5,6-dioxobenzo[*a*]phenazine 7-oxide (1e). Nitrosylsulfuric acid, prepared from sodium nitrite (2.50 g, 35 mmol) and concentrated sulfuric acid (15 ml) was added over 5 min to a solution of 4-(*o*-tolylamino)-1,2-naphthoquinone (2.63 g, 10 mmol) in glacial acetic acid (60 ml). The reaction mixture was stirred for 1 h at 15–20°C, then poured with stirring into ice/water mixture (200 ml). The formed precipitate was filtered off, washed with water until neutral reaction, and dried. Yield 2.60 g (90%), red crystals, mp 248°C (DMF). IR spectrum, ν, cm^{-1}: 1356 (N–O), 1672 (C=O). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.85 (3H, s, CH_3); 7.50–7.63 (2H, m, H-3,9); 7.90 (1H, d, *J* = 7.2, H-10); 7.96 (1H, t, *J* = 7.8, H-2); 8.11 (1H, d, *J* = 7.8, H-1); 8.31 (1H, d, *J* = 8.6, H-4); 8.85 (1H, d, *J* = 7.9, H-8). ^{13}C NMR spectrum, δ, ppm: 17.3 (CH_3); 117.4 (C-10); 126.7 (C-8); 128.4 (C-3); 131.1 (C-2); 132.2 (C-9); 132.3 (C-11a); 133.6 (C-12b); 135.0 (C-4a); 135.6 (C-1); 138.3 (C-7a); 139.1 (C-11); 142.5 (C-12a); 149.4 (C-6a); 171.5 (C-5); 177.7 (C-6). Found, *m*/*z*: 290.0684 $[M]^+$. $C_{17}H_{10}N_2O_3$. Calculated, *m*/*z*: 290.0686. Found, %: C 69.86; H 3.28; N 9.66. $C_{17}H_{10}N_2O_3$. Calculated, %: C 70.34; H 3.47; N 9.65.

11*H*-Indeno[1,2-*b*]quinoxalin-11-one (2a). Benzo[*a*]-phenazine-5,6-dione 7-oxide (**1a**) (0.8 g, 2.9 mmol) was added to a solution of KOH (1.0 g, 0.018 mol) in MeOH (15 ml), and the resulting mixture heated for 60 min at 20–25°C. Then 5% aqueous hydrochloric acid was added to the mixture. The precipitate was filtered off, washed with water followed by ethanol. Yield 0.56 g (83%), yellow crystals, mp 227°C (toluene) (mp 195–200°C[6], mp 222°C[7]). IR spectrum, ν, cm^{-1}: 1730 (C=O). UV spectrum, λ_{max}, nm (log ε): 286 (4.54). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 7.71 (1H, t, *J* = 7.2, H-3); 7.83–7.90 (2H, m, H-7,8); 7.88 (1H, d, *J* = 7.2, H-4), 7.92 (1H, t, *J* = 7.2, H-2); 8.08–8.13 (2H, m, H-6,9); 8.17 (1H, d, *J* = 7.2 , H-1). ^{13}C NMR spectrum, δ, ppm: 122.8 (C-4); 124.7 (C-2); 129.8 (C-7); 130.9 (C-8); 131.4 (C-3); 132.9 (C-6); 133.3 (C-9); 137.1 (C-11a); 137.4 (C-1); 141.5 (C-4a); 142.3 (C-5a); 142.6 (C-4b); 150.3 (C-9a); 156.9 (C-10a); 189.8 (C-11). Mass spectrum, *m*/*z* (I_{rel},%): 232 $[M]^+$(100), 204 (59), 76 (51), 32 (48). Found, %: C 77.61; H 3.42; N 11.84. $C_{15}H_8N_2O$. Calculated, %: C 77.58; H 3.47; N 12.06.

8-Methyl-11*H*-indeno[1,2-*b*]quinoxalin-11-one (2b) was synthesized analogously to compound **2a**. Yield 0.55 g (77%), yellow crystals, mp 230°C (benzene). IR spectrum, ν, cm^{-1}: 1720 (C=O). UV spectrum, λ_{max}, nm (log ε): 295 (4.55). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.56 (3H, s, 8-CH_3); 7.68 (1H, t, *J* = 7.8, H-3); 7.74 (1H, d, *J* = 8.5, H-7); 7.85 (1H, t, *J* = 7.8, H-2); 7.86 (1H, d, *J* = 7.8, H-4); 7.94 (1H, s, H-9); 8.01 (1H, d, *J* = 8.5, H-6); 8.04 (1H, d, *J* = 7.8, H-1). ^{13}C NMR spectrum, δ, ppm: 21.6 (CH_3); 122.6 (C-4); 124.7 (C-2); 129.4 (C-7); 130.4 (C-3); 133.0 (C-6); 134.9 (C-9); 136.9 (C-1); 137.4 (C-11a); 141.0 (C-8); 141.2 (C-4a); 141.6 (C-5a); 142.4 (C-4b), 150.1 (C-9a); 156.3 (C-10a); 190.0 (C-11). Mass spectrum, *m*/*z* (I_{rel},%): 246 $[M]^+$(100), 218 (39), 89 (36), 32 (71). Found, %: C 77.61; H 4.03; N 11.12. $C_{16}H_{10}N_2O$. Calculated, %: C 78.04; H 4.09; N 11.38.

8-Chloro-11*H*-indeno[1,2-*b*]quinoxalin-11-one (2c) was synthesized analogously to compound **2a**. Yield 0.45 g (58%), yellow crystals, mp 282°C (benzene). IR spectrum, ν, cm^{-1}: 1730 (C=O). UV spectrum, λ_{max}, nm (log ε): 291 (4.52). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 7.74 (1H, t, *J* = 7.5, H-3); 7.89 (1H, d, *J* = 7.5, H-4); 7.91 (1H, t, *J* = 7.5, H-2); 7.95 (1H, dd, *J* = 7.4, *J* = 2.4, H-7); 8.1 (1H, d, *J* = 7.4, H-6); 8.16 (1H, d, *J* = 7.5, H-1); 8.28 (1H, d, *J* = 2.4, H-9). ^{13}C NMR spectrum, δ, ppm: 122.6 (C-4); 124.9 (C-2); 130.4 (C-3); 130.7 (C-7); 132.8 (C-6); 133.2 (C-9); 136.1 (C-8); 136.7 (C-1); 137.0 (C-11a); 141.4 (C-4a); 141.7 (C-5a); 143.0 (C-4b); 150.8 (C-9a); 156.7 (C-10a); 189.6 (C-11). Mass spectrum, *m*/*z* (I_{rel},%): 268 $[M(^{37}Cl)]^+$ (35), 266 $[M(^{35}Cl)]^+$(100), 75 (45), 50 (35), 32 (24). Found, %: C 67.41; H 2.54; N 10.49; Cl 13.30. $C_{15}H_7ClN_2O$. Calculated, %: C 67.56; H 2.65; N 10.50; Cl 13.29.

8-Fluoro-11*H*-indeno[1,2-*b*]quinoxalin-11-one (2d) was prepared analogously to compound **2a**. Yield 0.59 g (81%), yellow crystals, mp 298°C (benzene). IR spectrum, ν, cm^{-1}: 1724 (C=O). UV spectrum, λ_{max}, nm (log ε): 288 (4.52). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 7.69–7.73 (2H, m, H-2,3); 7.81–7.86 (1H, m, H-7); 7.88 (1H, d, *J* = 7.5, H-4); 7.96 (1H, d, *J* = 10.0, H-6); 8.06 (1H, d, *J* = 7.5, H-1); 8.17–8.22 (1H, m, H-9). ^{13}C NMR spectrum, δ, ppm: 115.3 (C-7); 115.5 (C-9); 122.5 (C-4); 124.9 (C-2); 131.5 (C-3); 132.6 (C-6); 136.5 (C-1); 137.0 (C-11a); 140.3 (C-4a); 141.5 (C-5a); 143.6 (C-4b); 150.0 (C-9a); 156.2 (C-10a); 163.2 (C-8); 189.6 (C-11). Mass spectrum, *m*/*z* (I_{rel},%): 250 $[M]^+$(100), 222 (24), 94 (18), 75 (20), 50 (20). Found, %: C 72.27; H 2.80; N 11.47. $C_{15}H_7FN_2O$. Calculated, %: C 72.00; H 2.82; N 11.19.

6-Methyl-11*H*-indeno[1,2-*b*]quinoxalin-11-one (2e) was synthesized similar to compound **2a**. Yield 0.59 g (83%), yellow crystals, mp 210°C (toluene). IR spectrum, ν, cm^{-1}: 1716 (C=O). UV spectrum, λ_{max}, nm (log ε): 299 (4.55). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.78 (3H, s, 6-CH_3); 7.65 (1H, t, *J* = 7.5, H-3); 7.68 (1H, t, *J* = 7.5, H-1); 7.77 (1H, d, *J* = 7.2, H-7); 7.86 (1H, t, *J* = 7.2, H-8); 7.88 (1H, d, *J* = 7.5, H-4); 7.99 (1H, d, *J* = 8.0, H-9); 8.07 (1H, d, *J* = 7.5, H-1). ^{13}C NMR spectrum, δ, ppm: 17.2 (CH_3); 122.4 (C-4); 124.5 (C-2); 129.1 (C-7); 130.2 (C-8,9); 130.3 (C-8,9); 132.9 (C-3); 136.8 (C-6); 137.2 (C-1); 137.7 (C 4); 141.9 (C-4a); 141.4 (C-4b); 142.2 (C-5a); 149.6 (C-9a); 155.7 (C-10a); 189.8 (C-11). Found, *m*/*z*: 246.0789 $[M]^+$. $C_{16}H_{10}N_2O$. Calculated, *m*/*z*: 246.0788. Found, %: C 78.16; H 3.90; N 11.35. $C_{16}H_{10}N_2O$. Calculated, %: C 78.04; H 4.09; N 11.38.

11-Hydroxy-11-(pyrrolidin-1-ylcarbonyl)-11*H*-indeno-[1,2-*b*]quinoxaline 10-oxide (7a). Pyrrolidine (0.2 g, 2.8 mmol) was added with stirring over 10 min at 20–25°C to a solution of compound **1a** (0.56 g, 2.0 mmol) in tetrahydrofuran (10 ml). After 30 min, the formed precipitate was filtered off, washed on filter with water (50 ml), followed by ethanol (20 ml). Yield 0.53 g (76%), yellow crystals, mp 275°C (compounds **7a**–**c** begin to change visually at ~100°C). UV spectrum, λ_{max}, nm (log ε): 322 (4.47). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 1.63–1.73 (4H, m, 3,4-CH_2 pyrrolidine); 2.75–2.82 (2H, m) and 2.82–2.91 (2H, m, CH_2NCH_2); 7.68 (1H, t, *J* = 7.4, H-3); 7.82–7.89 (2H, m, H-7,8); 7.93 (1H, t, *J* = 7.4, H-2); 8.10 (1H, d, *J* = 7.4, H-1); 8.23 (1H, d, *J* = 8.4, H-6); 8.64 (1H, d, *J* = 8.4,

H-9); 8.73 (1H, d, *J* = 7.8, H-4); 8.83 (1H, s, OH). Found, %: C 69.32; H 4.76; N 11.98. $C_{20}H_{17}N_3O_3$. Calculated, %: C 69.15; H 4.93; N 12.10.

11-Hydroxy-8-methyl-11-(pyrrolidin-1-ylcarbonyl)-11*H*-indeno[1,2-*b*]quinoxaline 10-oxide (7b) was prepared from compound **1b** (0.59 g, 2.0 mmol) and pyrrolidine (0.37 g, 5.2 mmol) similar to compound **7a**. Yield 0.53 g (73%), yellow crystals, mp 245°C. UV spectrum, λ_{max}, nm (log ε): 326 (4.42). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 1.63–1.73 (4H, m, 3,4-CH_2 pyrrolidine); 2.66 (3H, s, CH_3); 2.75–2.83 (2H, m) and 2.84–2.89 (2H, m, CH_2NCH_2); 7.68 (1H, t, *J* = 7.6, H-3); 7.73 (1H, d, *J* = 7.3, H-7); 7.83 (1H, t, *J* = 7.4, H-2); 8.08–8.13 (2H, m, H-1,6); 8.42 (1H, s, H-9); 8.69 (1H, d, *J* = 7.6, H-4); 8.93 (1H, s, OH). Found, *m*/*z*: 362.1496 $[M+H]^+$. $C_{21}H_{20}N_3O_3$. Calculated, *m*/*z*: 362.1499. Found, %: C 69.82; H 5.09; N 11.30. $C_{21}H_{19}N_3O_3$. Calculated, %: C 69.79; H 5.30; N 11.63.

11-Hydroxy-6-methyl-11-(pyrrolidin-1-ylcarbonyl)-11*H*-indeno[1,2-*b*]quinoxaline 10-oxide (7c) was synthesized from compound **1e** (0.59 g, 2.0 mmol) and pyrrolidine (0.37 g, 5.2 mmol) analogously to compound **7a**. Yield 0.56 g (77%), yellow crystals, mp 250°C. UV spectrum, λ_{max}, nm (log ε): 327 (4.46). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 1.63–1.73 (4H, m, 3,4-CH_2 pyrrolidine); 2.86 (3H, s, CH_3); 2.75–2.83 (2H, m, CH_2NCH_2); 2.84–2.89 (2H, m, CH_2NCH_2); 7.65–7.77 (3H, m, H-3,7,8); 7.83 (1H, t, *J* = 7.5, H-2); 8.10 (1H, d, *J* = 7.5, H-1); 8.47 (1H, d, *J* = 8.3, H-9); 8.75 (1H, d, *J* = 7.7, H-4); 8.91 (1H, s, OH). Found, *m*/*z*: 362.1496 $[M+H]^+$. $C_{21}H_{20}N_3O_3$. Calculated, *m*/*z*: 362.1499. Found, %: C 69.53; H 5.01; N 11.69. $C_{21}H_{19}N_3O_3$. Calculated, %: C 69.79; H 5.30; N 11.63.

This work was financially supported by a grant of the Ministry of Education and Science of the Russian Federation (2014-2016 - project № 2854).

The authors are indebted to O. A. Chizhov (N. D. Zelinsky Institute of Organic Chemistry, Russian Academy of Sciences), A. A. Nefedov, and O. B. Statsenko (N. N. Vorozhtsov Novosibirsk Institute of Organic Chemistry, Siberian Branch of the Russian Academy of Sciences) for performing high-resolution mass spectral analysis.

References

1. Tsuda, T.; Fujishima, K.; Ueda, H. *Agric. Biol. Chem.* **1981**, *45*, 2129.
2. Rewcastle, G. W.; Denny, W. A.; Baguley, B. G. *J. Med. Chem.* **1987**, *30*, 843.
3. Chowdhury, G.; Sarkar, U.; Pullen, S.; Wilson, W.; Rajapakse, A.; Fuchs-Knotts, T.; Gates, K. *Chem. Res. Toxicol.* **2012**, *25*, 197.
4. Gonda, M.; Nieves, M.; Nunes, E.; Cerain, A.; Monge, A.; Lavaggi, M.; Gonzales, M.; Ceretto H. *Med. Chem. Commun*. **2013**, *4*, 595.
5. Lavaggi, M.; Cabrera, M.; Anavena, M.; Olea-Azar, C.; Cerain, A.; Antonio, M.; Pachon, G.; Cascante, M.; Bruno, A.; Pietrasanta, L.; Gonzalez, M.; Ceretto, H. *Bioorg Med. Chem.* **2010**, *18*, 4433.
6. Khan, M.; Munawar, M.; Ashraf, M.; Alam, U.; Ata, A.; Asiri, A.; Kousar, S.; Khan, M. *Bioorg. Med. Chem.* **2014**, *22*, 1195.
7. Pearson, B. D.; Mitch, R. A.; Cromwell, N. H. *J. Org. Chem*. **1962**, *27*, 1674.
8. Prostakov, N. S.; Pleshakov, V. G.; Zain-ul-Abedin, M.; Kordova, I. R.; Zakharov, V. F.; Zvolinskii, V. P. *Zh. Org. Khim.* **1982**, *3*, 640.
9. Zain-ul-Abedin, M.; Pleshakov, V. G.; Sergeeva, N. D.; Prostakov, N. S. *J. Bangladesh Acad. Sci.* **1996**, *20*, 17.
10. Daddy, L.; Desneves, J.; Ross, A. *Tetrahedron* **1993**, *49*, 9823.
11. Pretsch, E.; Bühlmann, P.; Affolter, C. *Structure Determination of Organic Compounds. Tables of Spectral Data* [in Russian]; Mir: Moscow, 2006, p. 116.
12. Schmidt, J.; Bauer, K. *Chem. Ber.* **1905**, 38, 3737.
13. Fischer, O.; Schindler, E. *Chem. Ber.* **1908**, 41, 392.
14. Belyakov, P. A., Kadentsev, V. I., Chizhov, A. O., Kolotyrkina, N. G., Shashkov, A. S., Ananikov, V. P. *Mendeleev Commun.* **2010**, *20*, 125.
15. Gornostaev, L. M.; Arnold, E. V.; Lyashchenko, T. A. *Chem. Heterocycl. Compd.* **2014**, *49*, 1827. [*Khim. Geterotsikl. Soedin.* **2013**, 1972.]
16. Harmon, R. E., Phipps, L. M., Howell, J. A., Gupta, S. K. *Tetrahedron*. **1969**, ***25***, 5807.