ISSN 1070-4280, Russian Journal of Organic Chemistry, 2020, Vol. 56, No. 2, pp. 213–217. © Pleiades Publishing, Ltd., 2020.
Russian Text © The Author(s), 2020, published in Zhurnal Organicheskoi Khimii, 2020, Vol. 56, No. 2, pp. 204–209.

Synthesis of Novel Spiro[chromene-4,3'-indolines] and Spiro(indoline-3,4'-pyrano[3,2-*h*]quinolines)

S. A. Pogosyan[a,*], M. V. Pogosyan[b], and A. A. Harutyunyan[a,c]

[a] *Scientific and Technological Center of Organic and Pharmaceutical Chemistry, NAS of Armenia, Yerevan, 0019 Armenia*
[b] *University of Cologne, Cologne, 50923 Germany*
[c] *Armenian–Russian University, Yerevan, 0051 Armenia*
**e-mail: safar.poghosyan@gmail.com*

Received July 30, 2019; revised December 13, 2019; accepted December 16, 2019

Abstract—The condensation of 1-alkylisatines with malononitrile and 8-hydroxyquinoline or 5,5-dimethyl-cyclohexane-1,3-dione in the presence of an aqueous solution of trimethylamine proceeds regioselectively as a one-pot three-component domino process to form spiro[chromene-4,3'-indoline] and spiro(indoline-3,4'-pyrano[3,2-*h*]-quinoline).

Keywords: 1-alkylisatines, malononitrile, 8-hydroxyquinoline, 5,5-dimethylcyclohexane-1,3-dione, three-component condensation, spiro(indoline-3,4'-pyrano [3,2-*h*]quinoline), spiro[chromene-4,3'-indoline]

DOI: 10.1134/S1070428020020062

Multicomponent reactions, which involve 1*H*-Indole-2,3-dione (isatin) and occur as one-pot catalytic domino processes, are the most common and efficient methods of synthesis of spiro-fused heterocyclic compounds [1].

The three-component reactions of isatin with malononitrile or cyanoacetic ester, and compounds with an enolic component or its synthetic equivalent in the structure were used to obtain a great number of carbo- and heterocyclic spirooxindoles, which are of interest for medical or combinatorial chemistry [2, 3].

As known, natural or synthetic oxindoles exhibit diverse biological activities, including a wide range of biological activity, including DNA-damaging [4], cytotoxic [5–7], fungicidal [8], antibacterial [9], and others.

Proceeding with our research into the synthesis of spiro-fused isatins by base-catalyzed three-component reactions [10, 11] and aiming at expanding the combinatorial potential of this synthetic approach, we involved in such reactions 1-substituted isatins, malononitrile, and 5,5-dimethylhexane-1,3-dione (dimedone) or 8-hydroxyquinoline.

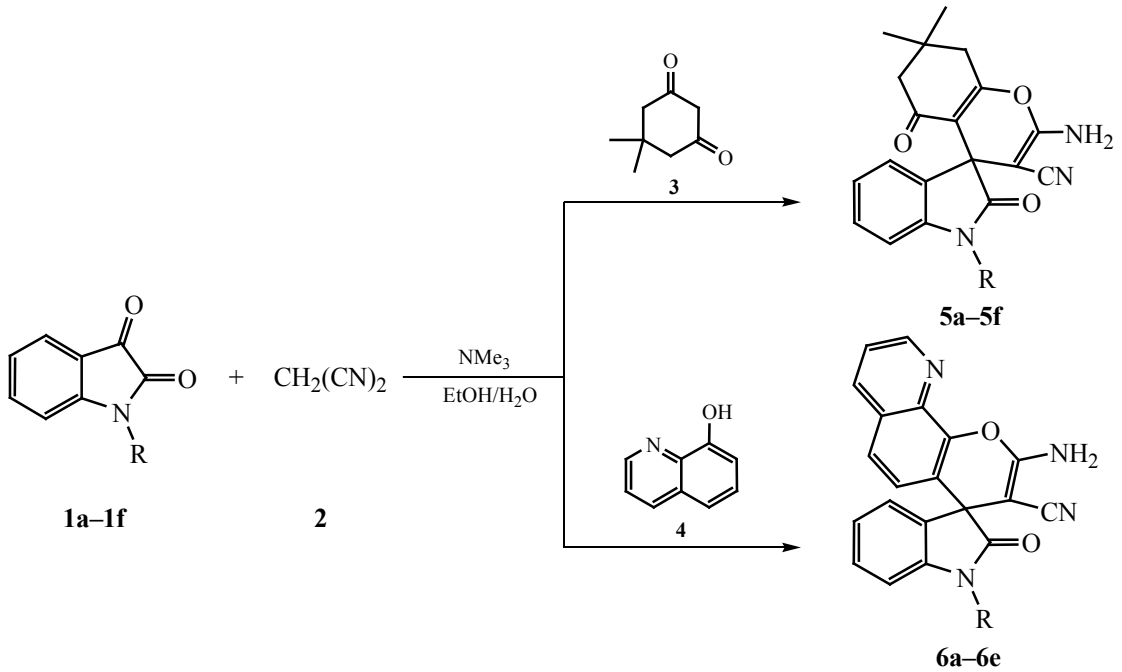
It was shown that the one-pot three-component condensation of the mentioned compounds in ethanol in the presence of an aqueous solution of trimethylamine occurs in a regioselective fashion by a cascade mechanism to form spiro-fused 2-oxindoles: spiro(chromene-4,3'-indoline) derivatives in the case of dimedone and spiro(indoline-3,4'-pyrano[3,2-*h*]quinoline) derivatives in the case of 8-hydroxyquinoline. The synthesized novel spiro-fused compounds combine two different heterocyclic system comprising a carbocycle and three different heterocycles, which determines the spectrum of their biological activity.

The syntheses realized in the present work are presented in Scheme 1. The suggested mechanism of the reaction is shown in Scheme 2.

The dielectrophile 2-(2-oxoindolin-3-ylidene)malononitrile (**7**) formed by the condensation of substituted isatin **1** and malononitrile (**2)** undergoes a regioselective Michael reaction with the participation of both electrophilic centers (the cyano group and the β-position of the activated double bond), leading to pyran ring closure; In both cases, the enolic OH group attacks exclusively the cyano group. The same reaction route was also suggested for similar syntheses of spiro-fused isatin derivatives [2, 10–13].

The IR spectra of the synthesized compounds contain characteristic ν(NH_2) bands at 3450–3150 cm^{-1}, ν(CN) bands at 2198–2190 cm^{-1}, and ν(C=O) bands at 1714–1680 cm^{-1}. The ^{13}C NMR spectra of the products containing a dimethylhexanone fragment display signals

Scheme 1.



1a–1f, **5a–5f**, **6a–6e**, R = H (**a**), CH_3 (**b**), C_2H_5 (**c**), C_3H_8 (**d**), C_4H_9 (**e**), Bn (**f**); **5a–e**, R = H (**a**), CH_3 (**b**), C_2H_5 (**c**), C_3H_7 (**d**), C_4H_9 (**e**), $CH_2C_6H_5$ (**f**); **6a–6e**, R = CH_3 (**a**), C_2H_5 (**b**), C_3H_8 (**c**), C_4H_9 (**d**), $CH_2C_6H_5$ (**e**).

at δ_C 31.6, 46.1, and 57.5 ppm assigned to the $\underline{C}(Me_2)$ carbon, quaternary spiro-oxindole carbon, and carbon atoms linked to the CN group, respectively.

To conclude, we would like to note that we still could not establish the absolute configuration of the synthesized 3-spiroindolines; the same situation was mentioned in some other publications concerning the synthesis of the spiro-fused isatin derivatives [6, 14, 15].

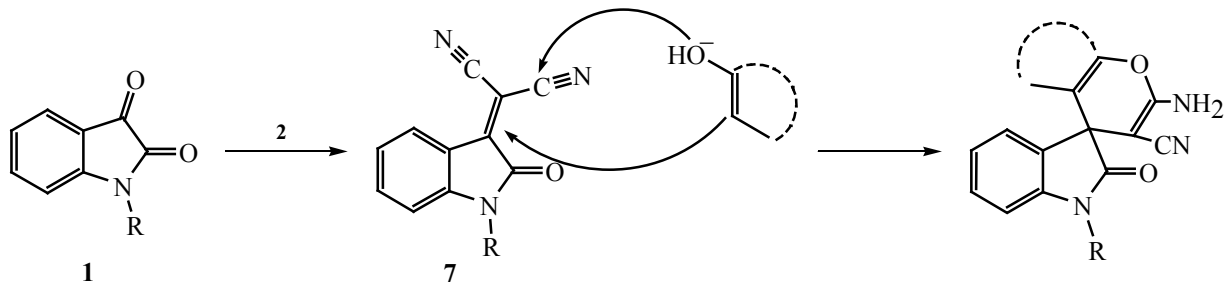
EXPERIMENTAL

Solvents were distilled before use and crystalline substances were recrystallized from appropriate solvents.

The IR spectra were measured on a Thermo Nicolet Avatar 330 instrument in mineral oil. The ^1H and ^{13}C NMR spectra were run on a Varian Mercury-300 VX spectrometer at 300 and 75.46 MHz, in DMSO-d_6–CCl_4 (1 : 3), internal reference TMS. The elemental analyses were obtained on a Eurovector EA 3000 analyzer. Thin-layer chromatography was performed on Silufol UV-254 plates in ethanol–benzene (2 : 5), visualization in iodine vapor.

Spiro[chromene-4,3'-indolines] 5a–5e and spiro-(indoline-3,4'-pyrano[3,2-*h*]quinolines 6a–6e (*general procedure*). A mixture of 20 mmol of isatine **1a–1f**, malononitrile (**2**), 5,5-dimethylcyclohexane-1,3-dione (**3**) or 8-hydroxyquinoline (**4**) and 1 mL of aqueous trimethylamine in 80 mL of ethanol was stirred under reflux for

Scheme 2.



2 h, after which 40 mL of the solution was distilled off, and the remaining solution was left to stand in the cold. The crystals that formed were filtered off and recrystallized from ethanol.

2-Amino-7,7-dimethyl-2',5-dioxo-5,6,7,8-tetrahydrospiro[chromene-4,3'-indoline]-3-carbonitrile (5a). Yield 5.5 g (82%), mp 280–282°C, R_f 0.24. IR spectrum, ν, cm^{-1}: 3368, 3246 (NH' NH_2), 1686 (C=O), 1604-1590 (C=C). ^{1}H NMR spectrum, δ, ppm: 1.07 s and 1.12 s (6H, Me_2), 2.09 d and 2.19 d [2H, 6,8-H(CH_2), *J* 15.9 Hz], 2.52 d and 2.61 d [2H, 6,8-H(CH_2), *J* 17.6 Hz], 6.80–6.94 m (3H) and 7.11 t.d (1H, C_6H_4, *J* 7.5, 1.5 Hz), 6.84 br.s (2H, NH_2), 10.26 s (1H, NH). Found, %: C 68.02; H 5.15; N 12.53. $C_{19}H_{17}N_3O_3$. Calculated, %: C 68.05; H 5.11; N 12.53.

2-Amino-2,5'-dioxo-1',7,7-trimethyl-5,6,7,8-tetrahydrospiro[chromene-4,3'-indoline]-3-carbonitrile (5b). Yield 4.80 g (70%), mp 273–275°C. R_f 0.64. IR spectrum, ν, cm^{-1}: 3284, 3107 (NH_2), 2192 (CN), 1701, 1682, 1666 (C=O), 1602 (C=C). ^{1}H NMR spectrum, δ, ppm: 1.07 s and 1.12 s (6H, Me_2), 2.08 d and 2.16 d [2H, 6,8-H(CH_2), *J* 16.0 Hz], 2.54 d and 2.61 d [2H, 6,8-H(CH_2), *J* 17.5 Hz], 3.20 s (3H, NCH_3), 6.87–7.01 m (3H, C_6H_4), 6.90 br.s (2H, NH_2), 7.23 d.d.d (1H, C_6H_4, *J* 7.6, 6.9, 2.2 Hz). ^{13}C NMR spectrum, δ, ppm: 25.9, 27.2, 27.7, 31.6, 40.1, 46.2, 49.9, 57.2, 107.5, 110.8, 116.5, 121.8, 122.2, 127.8, 133.2, 143.4, 158.5, 163.2, 175.9, 193.4. Found, %: C 68.72; H 5.45; N 12.15. $C_{20}H_{19}N_3O_3$. Calculated, %: C 68.75; H 5.48; N 12.03.

2-Amino-7,7-dimethyl-2,5'-dioxo-1'-ethyl-5,6,7,8-tetrahydrospiro[chromene-4,3'-indoline]-3-carbonitrile (5c). Yield 3.62 g (50%), mp 278–280°C, R_f 0.73. IR spectrum, ν, cm^{-1}: 3271, 3157 (NH_2), 2198 (CN), 1698, 1680 (C=O), 1634, 1611, 1602 (C=C). ^{1}H NMR spectrum, δ, ppm: 1.07 s (3H, CH_3), 1.13 s (3H, CH_3), 1.28 t (3H, CH_3, *J* 7.2 Hz), 2.08 d (1H, CH_2, *J* 16.0 Hz) and 2.18 d (1H, CH_2, *J* 16.0 Hz), 2.53 d (1H, CH_2, *J* 17.6 Hz) and 2.62 d (1H, CH_2, *J* 17.6 Hz), 3.74 q (2H, NCH_2, *J* 7.2 Hz), 6.86 br.s (2H, NH_2), 6.88 br.d (1H, C_6H_4, *J* 7.8 Hz), 6.94 t.d (1H, C_6H_4, *J* 7.3, 0.9 Hz), 6.98 d.d.d (1H, C_6H_4, *J* 7.3, 1.7, 0.5 Hz), 7.22 d.d.d (1H, C_6H_4, *J* 7.7, 7.3, 1.7 Hz). ^{13}C NMR spectrum, δ, ppm: 11.7, 27.1, 27.8, 31.6, 34.1, 40.1, 46.0, 49.8, 57.5, 107.5, 110.8, 116.4, 121.5, 122.4, 127.8, 133.4, 142.3, 158.4, 163.0, 175.3, 193.3. Found, %: C 69.62; H 5.75; N 11.53. $C_{21}H_{21}N_3O_3$. Calculated, %: C 69.41; H 5.82; N 11.56.

2-Amino-7,7-dimethyl-2,5'-dioxo-1'-propyl-5',6',7',8'-tetrahydrospiro[chromene-4,3'-indoline]-3-carbonitrile (5d). Yield 5.2 g (69%), mp 248–247°C, R_f 0.80. IR spectrum, ν, cm^{-1}: 3276, 3162 (NH_2), 2196 (CN), 1698, 1678 (C=O), 1633, 1609 (C=C). ^{1}H NMR spectrum, δ, ppm: 1.02 t (3H, CH_3, *J* 7.4 Hz), 1.07 s (3H, CH_3), 1.12 s (3H, CH_3), 1.74 sextet (2H, C<u>H</u>$_2$CH$_3$, *J* 7.4 Hz), 2.07 d (1H) and 2.18 d (1H, CH_2, *J* 16.0 Hz), 2.52 d (1H) and 2.62 d (1H, CH_2, *J* 17.6 Hz), 3.55–3.73 m (2H, NCH_2), 6.87 br.d (1H, C_6H_4, *J* 7.6), 6.88 br.s (2H, NH_2), 6.93 d.d.d (1H, C_6H_4, *J* 7.3, 7.3, 1.0 Hz), 6.98 d.d (1H, C_6H_4, *J* 7.3, 1.7 Hz), 7.21 d.d.d (1H, C_6H_4, *J* 7.6, 7.3, 1.7 Hz). ^{13}C NMR spectrum, δ, ppm: 11.1 (CH_3 Pr), 20.0 (CH_2), 27.1 (CH_3), 27.8 (CH_3), 31.6, 40.1 (CH_2), 41.3 (CH_2), 46.1, 49.8 (NCH_2), 57.5 (<u>C</u>CN), 107.6 (CH), 110.8, 116.4 (CN), 121.6 (CH), 122.4 (CH), 127.7 (CH), 133.3, 142.9, 158.4, 163.1, 175.7, 193.3. Found, %: C 70.12; H 5.96; N 11.38. $C_{22}H_{23}N_3O_3$. Calculated, %: C 70.05; H 6.14; N 11.13.

2-Amino-1'-butyl-7,7-dimethyl-2,5'-dioxo-5,6,7,8-tetrahydrospiro[chromene-4,3'-indoline]-3-carbonitrile (5e). Yield 5.7 g (73%), mp 247–248°C, R_f 0.80. IR spectrum, ν, cm^{-1}: 3360, 3288, 3149 (NH_2), 2193 (CN), 1702, 1684, 1668 (C=O), 1603 (C=C). ^{1}H NMR spectrum, δ, ppm: 1.00 t (3H, CH_3, *J* 7.3 Hz); 1.07 s (3H, CH_3), 1.13 s (3H, CH_3), 1.41–1.53 m (2H, C<u>H</u>$_2$CH$_3$), 1.64–1.75 m (2H, C<u>H</u>$_2$C$_2$H$_5$), 2.08 d (1H, CH_2, *J* 15.9 Hz), 2.19 d (1H, CH_2, *J* 15.9 Hz), 2.52 d (1H, CH_2, *J* 17.6 Hz), 2.62 d (1H, CH_2, *J* 17.6 Hz), 3.58–3.76 m (2H, NCH_2), 6.85 br.s (2H, NH_2), 6.85–7.00 m (3H, C_6H_4), 7.21 t.d (1H, C_6H_4, *J* 7.5, 1.7 Hz). ^{13}C NMR spectrum, δ, ppm: 13.4 (CH_3), 19.5 (CH_3), 27.2 (CH_3), 27.8 (CH_3), 28.7 (CH_2), 31.6 (CMe_2), 39.3 (CH_2), 40.1 (CH_2), 46.1 (C_{spiro}), 49.9 (CH_2), 57.6 (<u>C</u>CN), 107.6 (CH), 110.8, 116.4, 121.5 (CH), 122.4 (CH), 127.7 (CH), 133.4, 142.8, 158.4, 163.1, 175.6, 193.3. Found, %: C 70.33; H 6.28; N 10.95. $C_{23}H_{25}N_3O_3$. Calculated, %: C 70.57; H 6.44; N 10.73.

2-Amino-1'-benzyl-7,7-dimethyl-2,5'-dioxo-5',6',7',8'-tetrahydrospiro[chromene-4,3'-indoline]-3-carbonitrile (5f). Yield 5.4 g (64%), mp 248–247°C, R_f 0.80. IR spectrum, ν, cm^{-1}: 3380, 3320, 3206 (NH_2), 2197 (CN), 1714, 1680, 1660 (C=O), 1601 (C=C). ^{1}H NMR spectrum, δ, ppm: 1.10 s (3H, CH_3), 1.15 s (3H, CH_3), 2.14 d (1H, CH_2, *J* 15.9 Hz), 2.24 d (1H, CH_2, *J* 15.9 Hz), 2.57 d (1H, CH_2, *J* 17.5 Hz), 2.66 d (1H, CH_2, *J* 17.5 Hz), 4.90 d (1H, NCH_2, *J* 16.2 Hz), 4.97 d (1H, NCH_2, *J* 16.2 Hz), 6.59 d (1H$_{arom}$, *J* 7.7 Hz), 6.91–7.12 m (3H$_{arom}$), 6.96 br.s (2H, NH_2), 7.20–7.34 m (3H$_{arom}$), 7.44–7.49 m (2H$_{arom}$). ^{13}C NMR spectrum, δ, ppm: 27.2 (CH_3), 27.8 (CH_3), 31.6 (<u>C</u>Me$_2$), 40.1 (CH_2), 43.4 (CH_2),

46.3 (C_{spiro}), 49.8 (CH_2), 57.4 (<u>C</u>CN), 108.5 (CH), 110.8, 116.8, 121.9 (CH), 122.3 (CH), 126.5 (CH), 126.6 (2CH), 127.6 (CH), 127.9 (2CH), 133.2, 135.6, 142.4, 158.5, 163.4, 176.1, 193.6. Found, %: C 73.44; H 5.41; N 9.84. $C_{26}H_{23}N_3O_3$. Calculated, %: C 73.39; H 5.45; N 9.88.

2'-Amino-1-methyl-2-oxospiro(indoline-3,4'-pyrano[3,2-*h*]quinoline)-3'-carbonitrile (6a). Yield 4.6 g (65%), mp 355–357°C, R_f 0.64. IR spectrum, ν, cm^{-1}: 3416, 3301 (NH_2), 2192 (CN), 1720, 1660 (C=O), 1600 (C=C). ^1H NMR spectrum, δ, ppm: 3.30 s (3H, NCH_3), 6.59 d (1H, C_6H_2, *J* 8.6 Hz), 7.05–7.15 m (3H, C_6H_4), 7.20 br.s (2H, NH_2), 7.38 t.d (1H, C_6H_4, *J* 7.6, 1.6 Hz), 7.48 d (1H, C_6H_2, *J* 8.7 Hz), 7.54 d.d (1H, 8'-$H_{quinoline}$, *J* 8.3, 4.2 Hz), 8.22 d.d (1H, 7'-$H_{quinoline}$, *J* 8.3,1.6 Hz), 8.95 d.d (1H, 9'-$H_{quinoline}$, *J* 4.2, 1.6 Hz). Found, %: C 71.21; H 3.87; N 15.65. $C_{21}H_{14}N_4O_2$. Calculated, %: C 71.18; H 3.98; N 15.81.

2'-Amino-1-ethyl-2-oxospiro(indoline-3,4'-pyrano[3,2-*h*]quinoline)-3'-carbonitrile (6b). Yield 4.5 g (61%), mp 318–321°C, R_f 0.61. IR spectrum, ν, cm^{-1}: 3408, 3122 (NH_2), 2192 (CN), 1699, 1652 (C=O), 1620 (C=C). ^1H NMR spectrum, δ, ppm: 1.30 t (3H, CH_3, *J* 7.1 Hz), 3.76–3.89 m (2H, CH_2), 6.57 d (1H_{arom}, *J* 8.7 Hz), 7.04–7.15 m (3H_{arom}), 7.27 br.s (2H, NH_2), 7.37 t.d (1H, C_6H_4, *J* 7.6, 1.4 Hz), 7.52 d (1H_{arom}, *J* 8.7 Hz), 7.58 d.d (1$H_{quinoline}$, *J* 8.3, 4.2 Hz), 8.26 d.d (1$H_{quinoline}$, *J* 8.3, 1.6 Hz), 8.97 d.d (1$H_{quinoline}$, *J* 4.2, 1.6 Hz). Found, %: C 71.61; H 4.16; N 15.05. $C_{22}H_{16}N_4O_2$. Calculated, %: C 71.73; H 4.38; N 15.21.

2'-Amino-1-propyl-2-oxospiro(indoline-3,4'-pyrano[3,2-*h*]quinoline)-3'-carbonitrile (6c). Yield 4.9 g (64%), mp 316–318°C, R_f 0.68. IR spectrum, ν, cm^{-1}: 3321, 3194 (NH_2), 2192 (CN), 1716, 1660 (C=O), 1608 (C=C). ^1H NMR spectrum, δ, ppm: 1.00 t (3H, CH_3, *J* 7.4 Hz), 1.71–1.84 m (2H, C<u>H</u>$_2$CH$_3$), 3.66–3.83 m (2H, NCH_2), 6.58 d (1H, 5'-$H_{quinoline}$, *J* 8.6 Hz), 7.03–7.16 m (3H_{arom}), 7.19 br.s (2H, NH_2), 7.35 t.d (1H, C_6H_4, *J* 7.6, 1.5 Hz), 7.48 d (1H, 6'-$H_{quinoline}$, *J* 8.6 Hz), 7.54 d.d (1H, 8'-$H_{quinoline}$, *J* 8.2, 4.2 Hz), 8.21 d.d (1H, 7'-$H_{quinoline}$, *J* 8.2, 1.5 Hz), 8.95 d.d (1H, 9'-$H_{quinoline}$, *J* 4.2, 1.5 Hz). ^{13}C NMR spectrum, δ, ppm: 10.9, 20,2, 41.2, 50.4, 54.3, 108.5, 117.6, 118.5, 121.9, 122.7, 123.4, 123.6, 124.7, 128.1, 128.9, 133.7, 135.5, 137.6, 142.5, 144.2, 149.7, 161.0, 176.5. Found, %: C 72.16; H 4.65; N 14.40. $C_{23}H_{18}N_4O_2$. Calculated, %: C 72.24; H 4.74; N 14.65.

2'-Amino-1-butyl-2-oxospiro(indoline-3,4'-pyrano[3,2-*h*]quinoline)-3'-carbonitrile · C_2H_5OH (6d). Yield 6.2 g (70%), mp 316–318°C, R_f 0.72. IR spectrum, ν, cm^{-1}: 3360 (EtOH), 3288, 3149 (NH_2), 2193 (CN), 1702, 1684, 1668 (C=O), 1603 (C=C). ^1H NMR spectrum, δ, ppm: 0.99 t (3H, CH_3, *J* 7.3 Hz), 1.10 t (3H, CH_3, *J* 7.0 Hz), 1.38–1.50 m (2H, C<u>H</u>$_2$CH$_3$), 1.65–1.78 m (2H, C<u>H</u>$_2$C$_2$H$_5$), 3.41–3.51 m (2H), 3.68–3.89 m (3H, NCH_2, OCH_2, OH), 6.57 d (1H_{arom}, *J* 8.7 Hz), 7.03–7.16 m (3H, C_6H_4), 7.16 br.s (2H, NH_2), 7.35 t.d (1H, C_6H_4, *J* 7.6, 1.2 Hz), 7.47 d (1H_{arom}, *J* 8.7 Hz), 7.53 d.d (1H, 8'-$H_{quinoline}$, *J* 8.3, 4.2 Hz), 8.20 d.d (1H, 7'-$H_{quinoline}$, *J* 8.3, 1.6 Hz), 8.95 d.d (1H, 9'-$H_{quinoline}$, *J* 4.2, 1.6 Hz). ^{13}C NMR spectrum, δ, ppm: 13.3, 18.1, 19.4, 28.9, 39.3, 50.3, 54.3, 56.0, 108.3, 117.5, 118.4, 121.8, 122.6, 123.3, 123.5, 124.7, 128.0, 128.8, 133.8, 135.3, 135.4, 137.7, 142.5, 144.2, 149.6, 161.0, 176.3. Found, %: C 72.58; H 5.31; N 14.29. $C_{24}H_{20}N_4O_2$. Calculated, %: C 72.71; H 5.08; N14.13.

2'-Amino-1-benzyl-2-oxospiro(indoline-3,4'-pyrano[3,2-*h*]quinoline)-3'-carbonitrile (6e). Yield 5.5 g (69%), mp 333–335°C, R_f 0.66. IR spectrum, ν, cm^{-1}: 3321, 3178 (NH_2), 2192 (CN), 1696, 1656 (C=O), 1608 (C=C). ^1H NMR spectrum, δ, ppm: 4.95 and 5.04 d (1H and 1H, CH_2, *J* 15.7 Hz), 6.59 d (1H, 5'/6'-$H_{quinoline}$, *J* 8.6 Hz), 6.93 br.d (1H, 7-$H_{isatine}$, *J* 7.8 Hz), 7.05 d.d.d (1H, 5-$H_{isatine}$, *J* 7.8, 7.4, 0.7 Hz), 7.16 d.d (1H, 4-$H_{isatine}$, *J* 7.4, 1.2 Hz), 7.22–7.41 m (8H, H_{arom}, NH_2, C_6H_5), 7.49 d (1H, 5'/6'-$H_{quinoline}$, *J* 8.6 Hz), 7.55 d.d (1H, 8'-$H_{quinoline}$, *J* 8.3, 4.2 Hz), 8.23 d.d (1H, 7'-$H_{quinoline}$, *J* 8.3,1.7 Hz), 8.97 d.d (1H, 9'-$H_{quinoline}$, *J* 4.2, 1.7 Hz). Found, %: C 75.50; H 4.13; N 13.34. $C_{27}H_{18}N_4O_2$. Calculated, %: C 75.34; H 4.21; N 13.02.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Ziarani, G.M., Moradi, R., and Lashgari, N., *Arkivoc*, 2016, vol. i, p. 1. https://doi.org/10.3998/ark.5550190.p009.385
2. Heravi, M.M., Zakeri, M., and Moharami, A., *J. Chem. Sci*., 2012, vol. 124, p. 865. https://doi.org/10.1007/s12039012-0284-7
3. Esmaeili, A.A., Ghalandarabad, S.A., Mesbah, F., Tasmimi, M., Izadyar, M., Fakhari, A.R., and Salimi, A.R., *Tetrahedron*, 2015, vol. 71, p. 2458. https://doi.org/10.1016/j.tet.2015.01.055
4. Ma, J. and Hecht, S.M., *Chem. Commun*., 2004, p. 1190. https://doi.org/10.1039/b402925a
5. Galliford, C.V. and Scheidt, K.A., *Angew. Chem. Int. Ed*., 2007, vol. 46, p. 8748.

https://doi.org/10.1002/anie.200701342

6. Kidwai, M., Jain, A., Nemaysh, V., Kumar, R., and Luthra, P.M., *Med. Chem. Res*., 2013, vol. 22, p. 2717. https://doi.org/10.1007/s00044-012-0249-x
7. Tian, Y., Nam, S., Liu, L., Yakushijin, F., Yakushijin, K., Buettner, R., Liang, W., Yang, F., Ma, Y., Horne, D., and Jove, R., *PLoS ONE*, 2012, vol. 7, e49306, p. 1. https://doi.org/10.1371/journal.pone.0049306
8. Dandia, A., Singh, R., Khaturia, S., Merienne, C., Morgant, G., and Loupy, A., *Bioorg. Med. Chem*., 2006, vol. 14, p. 2409. https://doi.org/10.1016/j.bmc.2005.11.025
9. Khafagy, M.M., El-Wahab, A.H.F.A., Eid, F.A., and El-Agrody, A.M., *Farmaco*, 2002, vol. 57, p. 715. https://doi.org/10.1016/S0014-827X(02)01263-6
10. Pogosyan, S.A. Avakimyan, Dzh.A., and Stepanyan, G.M., *Russ. J. Org. Chem*., 2016, vol. 52, p. 1308. https://doi.org/10.1134/S1070428018120254
11. Pogosyan, S.A. Paronikyan, R.V., Stepanyan, G.M., and Grigoryan, A.G., *Khim. Zh. Arm*., 2016, vol. 69, p. 518.
12. Wang, J., Li, J., Liu, H., Xu, Z., and Zhu, S., *Lett. Org. Chem*., 2015, vol. 12, p. 62. https://doi.org/10.2174/1570178612011501121245 26
13. Zhao, H.W., Li, B., Tian, T., Meng, W., Yang, Z., Song, X.Q., Chen, X.Q., and Pang, H.L., *Eur. J. Org. Chem*., 2015, vol. 15, p. 3320. https://doi.org/10.1002/ejoc.201500152
14. Ghahremanzadeh, R., Hosseini, G., Akbarzadeh, R., and Bazgir, A., *J. Heterocycl. Chem*., 2013, vol. 50, p. 272. https://doi.org/10.1002/jhet.1010
15. Karamthulla, S., Pal, S., Khan, M.N., and Choudhury, L.H., *RSC Adv*., 2013, vol. 3, p. 15576. https://doi.org/10.1039/c3ra43289k