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Reaction of N-Heterocycles with Acetylenedicarboxylates in the Presence of *N*-Alkylisatins or Ninhydrin. Efficient Synthesis of Spiro Compounds

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Summary. The 1,3-dipolar intermediates generated by addition of isoquinoline, to dialkyl acetylenedicaboxylates are trapped by *N*-alkylisatins to produce dialkyl 1,2-dihydro-2-oxo-1-alkylspiro[3*H*-indol-3,2′-[2*H*,11b*H*][1,3]oxazino[2,3-*a*]isoquinoline]-3′,4′-dicarboxylates in excellent yields. The reaction of isoquinoline, quinoline, or pyridine with dimethyl acetylenedicarboxylate in the presence of ninhydrin led to dimethyl 1,2-dihydro-1,3-dioxospiro[3*H*-indene-3,2′-[2*H*,11b*H*][1,3]oxazino[2,3-*a*]isoquinoline]-3′,4′-dicarboxylate, dimethyl 1,2-dihydro-1,3-dioxospiro[3*H*-indene-3,3′[3*H*,4a*H*][1,3]oxazino[3,2-*a*]quinoline]-1,2-dicarboxylate, or dimethyl 1,2-dihydro-1,3-dioxospiro[3*H*-indene-3,2′-[2*H*,9a*H*]pyrido[2,1-*b*][1,3]oxazino]-3,4-dicarboxylate.

Keywords. Spiro compounds; Triphenylphosphine; Acetylenedicarboxylates; *N*-Alkylisatins; N-Heterocycles.

Introduction

Spiro compounds having cyclic structures fused at a central carbon are of interest due to their interesting conformational features and their structural implications on biological systems [1]. The asymmetric characteristic of the molecule due to the chiral spiro carbon is one of the important criteria of the biological activities. The presence of the sterically constrained spiro structure in various natural products also adds to the interest in the investigations of spiro compounds [2]. The basic principles of dipolar cycloaddition reactions were provided by the work of *Huisgen* [3]. An interesting example of this type is the dipole generated from isoquinoline and dimethyl acetylenedicarboxylate (*DMAD*), whose existence was established by *Huisgen et al.* [4].

As part of our current studies on the development of new routes towards heterocyclic systems [5], we describe an efficient synthesis of dialkyl 1,2-dihydro-2-oxo-1-alkylspiro[3*H*-indol-3,2′-[2*H*,11b*H*][1,3]oxazino[2,3-*a*]isoquinoline]-3′,4′-dicarboxylates (**1**).

Results and Discussion

The reaction of isoquinoline (**2**) and dialkyl acetylenedicarboxylates **3** in the presence of *N*-alkylisatins **4** proceeds smoothly in CH_2Cl_2 at ambient temperature to produce the two diastereoisomers of spiro compounds **1** in nearly 2:1 ratio and high yields (Scheme 1). Our attempts to separate these diastereoisomers (Scheme 2) were unsuccessful.

The structures of compounds **1a–1f** were deduced from their elemental analyses and their IR, ^{1}H NMR, and ^{13}C NMR spectra. For example, in the ^{1}H NMR spectrum for the major isomer of **1a**, signals due to the two methoxy groups were visible at $\delta = 3.29$ and 3.98 ppm; the corresponding signals for the minor isomer of **1a** were observed at $\delta = 3.25$ and 3.96 ppm. The ring junction proton of the major isomer of **1a** was discernible as a singlet at $\delta = 7.08$ ppm; the corresponding signal for the minor isomer of **1a** was seen as a singlet at $\delta = 6.52$ ppm. In the ^{13}C NMR spectrum, the signals corresponding to ester and amide carbonyl groups of the major isomer of **1a** were observed at $\delta = 163.5$, 163.9, and 174.5 ppm. Those for the

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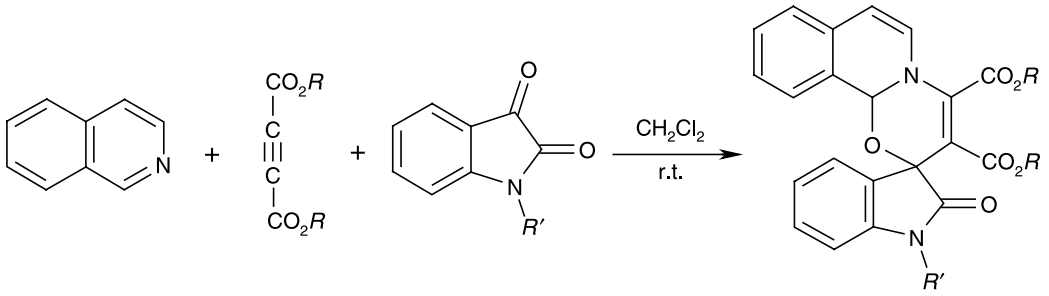


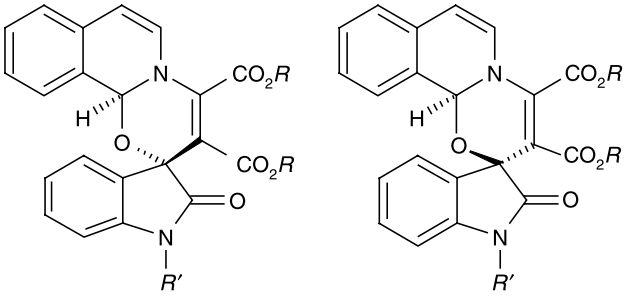
2

	R
3a	*Me*
3b	*Et*

	R
4a	*Me*
4b	*Et*
4c	*Bn*

	R	R′
1a	*Me*	*Me*
1b	*Et*	*Me*
1c	*Me*	*Bn*
1d	*Et*	*Bn*
1e	*Me*	*Et*
1f	*Et*	*Et*

Scheme 1



(*R*,*S*)-1 **(*S*,*S*)-1**

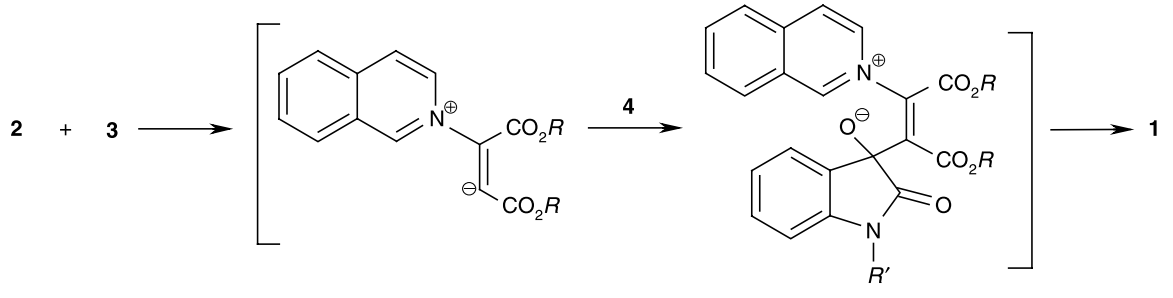
Scheme 2

minor isomer were visible at $\delta = 163.6$, 163.7, and 174.6 ppm. The mass spectrum of **1a** displayed the molecular ion peak at $m/z = 432$, which is consistent with the 1:1:1 adduct of isoquinoline, *DMAD* and *N*-methylisatin.

Mechanistically, it is conceivable that the reaction involves the initial formation of a 1,3-dipolar intermediate **5** between isoquinoline and the acetylenic compound [6–8], which reacts with the carbonyl group of *N*-alkylisatin to produce **6**. Cyclization of this zwitterionic intermediate leads to the spiro compound **1** (Scheme 3).

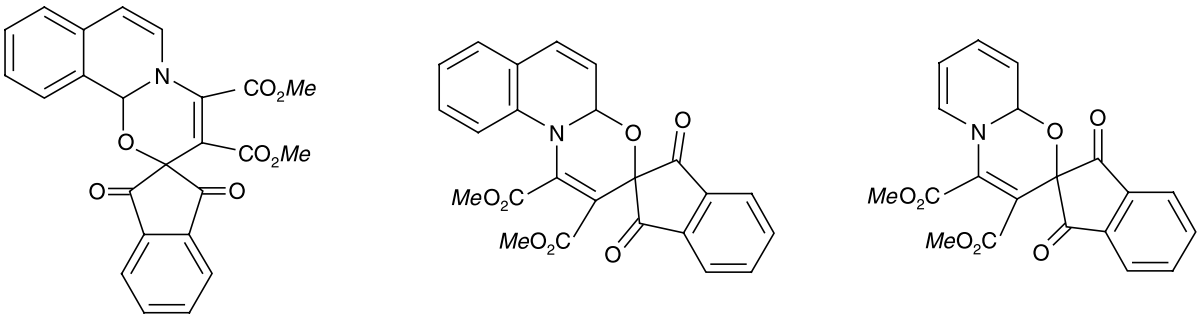
The reaction of isoquinoline, quinoline, or pyridine with *DMAD* in the presence of ninhydrin led to dimethyl 1,2-dihydro-1,3-dioxospiro [3*H*-indene-3,2′-[2*H*,11b*H*][1,3]oxazino[2,3-*a*]isoquinoline]-3,4-dicarboxylate (**7**), dimethyl 1,2-dihydro-1,3-dioxospiro[3*H*-indene-3,3′-[3*H*,4a*H*][1,3] oxazino [3,2-*a*] quinoline]-1,2-dicarboxylate (**8**), or dimethyl 1,2-dihydro-1,3-dioxospiro[3*H*-indene-3,2′-[2*H*,9a*H*]pyrido[2,1-*b*][1,3]oxazino]-3,4-dicarboxylate (**9**) (Scheme 4).

In the ^{1}H NMR spectrum of **7**, signals due to the two methoxy groups were visible at $\delta = 3.47$ and 3.99 ppm. The ring junction proton of **7** was discernible as a singlet at $\delta = 6.77$ ppm. In ^{13}C NMR spectrum of **7**, the characteristic signal for the spiro



5 **6**

Scheme 3



7 **8** **9**

Scheme 4

carbon was observed at $\delta = 79.7$ ppm. The signals corresponding to the carbonyl groups of **7** were seen at $\delta = 163.0$, 163.9, and 190.8 ppm.

In conclusion, we have described a convenient route to dialkyl 1,2-dihydro-2-oxo-1-alkylspiro[3*H*-indol-3,2′-[2*H*,11b*H*][1,3]oxazino[2,3-*a*]isoquinoline]-3′,4′-dicarboxylates from N-heterocycles and dialkyl acetylenedicarboxylates in the presence of *N*-alkylisatins. The reaction of isoquinoline, quinoline, or pyridine with *DMAD* in the presence of ninhydrin led to dimethyl 1,2-dihydro-1,3-dioxospiro [3*H*-indene-3,2′-[2*H*,11b*H*][1,3]oxazino[2,3-*a*]isoquinoline]-3,4-dicarboxylate, dimethyl 1,2-dihydro-1,3-dioxospiro[3*H*-indene-3,3′-[3*H*,4*aH*][1,3]oxazino [3,2-*a*]quinoline]-1,2-dicarboxylate, or dimethyl 1,2-dihydro-1,3-dioxospiro[3*H*-indene-3,2′-[2*H*,9a*H*]-pyrido[2,1-*b*][1,3]oxazine-3,4-dicarboxylate. The functionalized spiro compounds reported in this work may be considered as potentially useful synthetic intermediates because they possess atoms with different oxidation states. The advantage of the present procedure is that the reaction is performed under neutral conditions by simply mixing the starting materials. The procedure described here provides an acceptable one-pot method for the preparation of spiro heterocyclic compounds.

Experimental

Compounds **2**–**4** were obtained from *Fluka* and were used without further purification. Mp: Electrothermal-9100 apparatus. IR Spectra: Shimadzu IR-460 spectrometer. ^{1}H and ^{13}C NMR spectra: Bruker DRX-500 AVANCE instrument; in $CDCl_3$ at 500.1 and 125.7 MHz, resp; δ in ppm, J in Hz. EI-MS (70 eV): Finnigan-MAT-8430 mass spectrometer, in m/z. Elemental analyses (C, H, N) were performed with a Heraeus CHN-O-Rapid analyzer. The results agreed favorably with the calculated values.

*General Procedure for the Preparation of Compounds **1**, **7**, **8**, and **9***

To a stirred solution of dialkyl acetylenedicarboxylate (2 mmol) and *N*-alkylisatin or ninhydrin (2 mmol) in 15 cm^3 CH_2Cl_2 was added the N-heterocycle (2 mmol) at room temperature. The reaction mixture was then stirred for 24 h. The solvent was removed under reduced pressure, and the residue was purified by CC (SiO_2; *n*-hexane/*Ac*O*Et* 4/1) to afford the pure title compounds.

Dimethyl 1,2-dihydro-2-oxo-1-methylspiro[3H-indole-3,2′-[2H,11bH][1,3]oxazino[2,3-a]isoquinoline]-3′,4′-dicarboxylate (**1a**, $C_{24}H_{20}N_2O_6$)

Yellow crystals, mp 210–212°C; yield 0.84 g, 97%; IR (KBr): $\bar{\nu} = 1742$, 1721, 1647, 1593, 1566 cm^{-1}; EI-MS: m/z (%) = 432 (M^+, 5), 401 (25), 302 (78), 161 (86), 129 (48), 104 (100), 76 (44), 59 (18); NMR data for the major isomer (67%); ^{1}H NMR: $\delta = 3.29$ (s, O*Me*), 3.46 (s, *Me*), 3.98 (s, O*Me*), 5.83 (d, $^3J = 7.3$ Hz, CH), 6.41 (d, $^3J = 7.2$ Hz, CH), 6.80 (d, $^3J = 7.7$ Hz, CH), 6.96 (t, $^3J = 7.4$ Hz, CH), 7.08 (s, CH), 7.11 (t, $^3J = 7.6$ Hz, CH), 7.16–7.26 (m, 4CH), 7.36 (d, $^3J = 7.5$ Hz, CH) ppm; ^{13}C NMR: $\delta = 26.3$ (N*Me*), 51.7, 53.4 (2O*Me*), 77.5 (CH), 79.7, 105.8 (2C), 105.3, 108.3 (2CH), 122.6, 122.9 (2C), 123.2, 123.3, 125.2, 126.2, 127.1, 128.3, 129.5, 129.8 (8CH), 130.2, 145.2, 145.3 (3C), 163.5, 163.9, 174.5 (3C=O) ppm; NMR data for the minor isomer (26%); ^{1}H NMR: $\delta = 3.25$ (s, O*Me*), 3.47 (s, *Me*), 3.96 (s, O*Me*), 5.81 (d, $^3J = 7.3$ Hz, CH), 6.40 (d, $^3J = 7.3$ Hz, CH), 6.52 (s, CH), 6.82 (d, $^3J = 7.7$ Hz, CH), 6.98 (t, $^3J = 7.4$ Hz, CH), 7.13 (t, $^3J = 7.6$ Hz, CH), 7.18–7.26 (m, 4CH), 7.41 (d, $^3J = 7.5$ Hz, CH) ppm; ^{13}C NMR: $\delta = 26.7$ (N*Me*), 51.9, 53.5 (2O*Me*), 78.0 (CH), 80.2 (C), 105.1 (CH), 105.4 (C), 108.4 (CH), 122.7, 123.0 (2C), 123.8, 124.1, 125.3, 125.9, 127.2, 128.5, 129.6, 129.9 (8CH), 130.5, 144.1, 144.7 (3C), 163.6, 163.7, 174.6 (3C=O) ppm.

Diethyl 1,2-dihydro-2-oxo-1-methylspiro[3H-indole-3,2′-[2H,11bH][1,3]oxazino[2,3-a]isoquinoline]-3′,4′-dicarboxylate (**1b**, $C_{26}H_{24}N_2O_6$)

Yellow crystals, mp 215–217°C; yield 0.87 g, 95%; IR (KBr): $\bar{\nu} = 1740$, 1719, 1650, 1590, 1560 cm^{-1}; EI-MS: m/z (%) = 460 (M^+, 12), 415 (48), 370 (78), 331 (96), 161 (48), 129

(56), 76 (44), 45 (100); NMR data for the major isomer (65%); ^{1}H NMR: $\delta = 0.91$, 1.41 (2t, $^3J = 7.1$ Hz, 2*Me*), 3.27 (s, N*Me*), 3.87, 4.39 (2q, $^3J = 7.1$ Hz, 2OCH$_2$), 5.80 (d, $^3J = 8.7$ Hz, CH), 6.41 (d, $^3J = 7.1$ Hz, CH), 6.48 (d, $^3J = 8.7$ Hz, CH), 6.81 (t, $^3J = 7.4$ Hz, CH), 7.04 (s, CH), 7.10 (t, $^3J = 7.6$ Hz, CH), 7.11–7.26 (m, 4CH), 7.36 (d, $^3J = 7.5$ Hz, CH) ppm; ^{13}C NMR: $\delta = 13.6$, 14.0 (2*Me*), 26.3 (N*Me*), 60.4, 62.7 (2OCH$_2$), 77.5 (C), 79.6 (CH), 104.9 (C), 105.2, 108.2 (2CH), 122.6, 123.0 (2C), 123.2, 123.4, 125.2, 126.2, 127.1, 128.3, 129.5, 129.9 (8CH), 130.1, 145.3, 145.6 (3C), 163.1, 163.2, 174.7 (3C=O) ppm; NMR data for the minor isomer (25%); ^{1}H NMR: $\delta = 0.86$, 1.37 (2t, $^3J = 7.1$ Hz, 2*Me*), 3.23 (s, N*Me*), 3.92, 4.49 (2q, $^3J = 7.1$ Hz, 2OCH$_2$), 5.86 (d, $^3J = 8.7$ Hz, CH), 6.45 (d, $^3J = 7.2$ Hz, CH), 6.48 (d, $^3J = 8.7$ Hz, CH), 6.53 (s, CH), 6.87 (t, $^3J = 7.4$ Hz, CH), 7.08 (t, $^3J = 7.6$ Hz, CH), 7.11–7.26 (m, 4CH), 7.39 (d, $^3J = 7.5$ Hz, CH) ppm; ^{13}C NMR: $\delta =$ 13.5, 13.9 (2*Me*), 26.7 (N*Me*), 60.6, 62.8 (2OCH$_2$), 78.1 (C), 80.2 (CH), 104.8 (C), 105.1, 108.3 (2CH), 122.6, 123.1 (2C), 123.8, 124.3, 125.1, 125.9, 127.7, 128.7, 129.6, 130.1 (8CH), 130.4, 144.1, 145.1 (3C), 163.0, 163.4, 173.7 (3C=O) ppm.

Dimethyl 1,2-dihydro-2-oxo-1-benzylspiro[3H-indole-3,2′-[2H,11bH][1,3]oxazino[2,3-a]isoquinoline]-3′,4′-dicarboxylate (**1c**, $C_{30}H_{24}N_2O_6$)

Yellow crystals, mp 235–237°C; yield 0.99 g, 98%; IR (KBr): $\bar{\nu} = 1738$, 1719, 1647, 1560, 1572 cm^{-1}; EI-MS: m/z (%) = 508 (M$^+$, 10), 477 (65), 446 (25), 417 (86), 129 (48), 91 (100), 76 (44), 31 (100); NMR data for the major isomer (67%); ^{1}H NMR: $\delta = 3.33$ (s, O*Me*), 4.0 (s, O*Me*), 5.11 (*AB* system, $^2J_{AB} = 15.4$ Hz, CH$_2$), 5.82 (d, $^3J = 6.2$ Hz, CH), 6.42 (d, $^3J = 6.2$ Hz, CH), 6.74 (d, $^3J = 7.7$ Hz, CH), 6.80 (d, $^3J = 7.6$ Hz, CH), 6.94 (t, $^3J = 7.3$ Hz, CH), 7.44 (s, CH), 7.03–7.44 (m, 10CH) ppm; ^{13}C NMR: $\delta = 44.9$ (CH$_2$), 51.6 (O*Me*), 53.4 (O*Me*), 77.5 (C), 79.5 (CH), 105.2 (C), 109.3 (CH), 123.1 (CH), 123.2 (CH), 123.4 (CH), 125.3 (CH), 126.3 (C), 127.1 (CH), 127.6 (2CH), 127.7 (CH), 128.1 (CH), 128.7 (C), 128.8 (3CH), 129.6 (CH), 129.8 (CH), 130.1 (CH), 135.8 (C), 144.3 (C), 145.5 (C), 163.6 (C=O), 163.7 (C=O), 174.7 (C=O) ppm; NMR data for the minor isomer (28%); ^{1}H NMR: $\delta = 3.34$ (s, O*Me*), 3.98 (s, O*Me*), 4.78 (*AB* system, $^2J_{AB} =$ 15.2 Hz, CH$_2$), 5.84 (d, $^3J = 7.0$ Hz, CH), 6.42 (d, $^3J = 7.0$ Hz, CH), 6.53 (s, CH), 7.03–7.44 (m, 13CH) ppm; ^{13}C NMR: $\delta = 44.5$ (CH$_2$), 51.8 (O*Me*), 53.6 (O*Me*), 78.1 (C), 80.1 (CH), 105.0 (C), 109.5 (CH), 122.9 (CH), 123.8 (CH), 124.2 (CH), 125.3 (CH), 127.0 (C), 127.2 (CH), 127.6 (2CH), 127.7 (CH), 128.5 (CH), 128.7 (C), 128.8 (3CH), 129.6 (CH), 129.8 (CH), 130.3 (CH), 135.7 (C), 144.2 (C), 145.5 (C), 163.5 (C=O), 163.9 (C=O), 173.7 (C=O) ppm.

Diethyl 1,2-dihydro-2-oxo-1-benzylspiro[3H-indole-3,2′-[2H,11bH][1,3]oxazino[2,3-a]isoquinoline]-3′,4′-dicarboxylate (**1d**, $C_{32}H_{28}N_2O_6$)

Yellow crystals, mp 240–242°C; yield 1.03 g, 96%; IR (KBr): $\bar{\nu} = 1742$, 1721, 1647, 1593, 1566 cm^{-1}; EI-MS: m/z (%) = 536 (M$^+$, 12), 491 (55), 446 (78), 238 (86), 129 (48), 91 (100), 76 (44), 45 (98); NMR data for the major isomer (60%); ^{1}H NMR: $\delta = 0.73$, 1.42 (2t, $^3J = 7.1$ Hz, 2*Me*), 3.73, 3.98 (2q, $^3J = 7.1$ Hz, 2OCH$_2$), 4.90 (*AB* system, $^2J_{AB} =$ 13.2 Hz, CH$_2$), 5.82 (d, $^3J = 7.8$ Hz, CH), 6.44 (d, $^3J = 7.7$ Hz, CH), 6.78 (d, $^3J = 7.8$ Hz, CH), 7.31 (s, CH), 7.02–7.45 (m, 12CH) ppm; ^{13}C NMR: $\delta = 13.5$, 13.9 (2*Me*), 44.5 (CH$_2$), 60.6, 62.8 (2OCH$_2$), 78.2 (C), 80.1 (CH), 104.2 (C), 109.4 (CH), 122.6 (CH), 123.2 (CH), 123.8 (CH), 125.9 (CH), 126.9 (C), 127.5 (CH), 127.7 (2CH), 127.8 (CH), 128.7 (CH), 128.8 (C), 128.9 (3CH), 129.8 (CH), 130.1 (CH), 130.2 (CH), 135.7 (C), 143.2 (C), 145.3 (C), 163.0 (C=O), 163.4 (C=O), 173.9 (C=O) ppm; NMR data for the minor isomer (25%); ^{1}H NMR: $\delta = 0.76$ (t, $^3J = 7.0$ Hz, *Me*), 1.44 (t, $^3J =$ 7.0 Hz, *Me*), 3.98, 4.12 (2q, $^3J = 7.1$ Hz, 2OCH$_2$), 4.98 (*AB* system, $^2J_{AB} = 14.0$ Hz, CH$_2$), 5.90 (d, $^3J = 7.6$ Hz, CH), 6.45 (d, $^3J = 7.6$ Hz, CH), 6.52 (s, CH), 7.03 (d, $^3J = 7.6$ Hz, CH), 7.07–7.45 (m, 12CH) ppm; ^{13}C NMR: $\delta = 13.3$ (*Me*), 14.0 (*Me*), 44.3 (CH$_2$), 60.4 (OCH$_2$), 62.5 (OCH$_2$), 79.4 (C), 80.2 (CH), 105.1 (C), 108.4 (CH), 122.9 (CH), 123.5 (CH), 124.0 (CH), 125.3 (CH), 127.0 (C), 127.4 (CH), 127.6 (2CH), 127.7 (CH), 128.8 (CH), 129.0 (C), 129.1 (3CH), 129.6, 130.2, 131.3 (8CH), 135.7, 143.0, 144.3 (3C), 163.6, 164.0, 174.4 (3C=O) ppm.

Dimethyl 1,2-dihydro-2-oxo-1-ethylspiro[3H-indole-3,2′-[2H,11bH][1,3]oxazino[2,3-a]isoquinoline]-3′,4′-dicarboxylate (**1e**, $C_{25}H_{22}N_2O_6$)

Yellow powder, mp 223–225°C; yield 0.84 g, 95%; IR (KBr): $\bar{\nu} = 1742$, 1721, 1647, 1593, 1566 cm^{-1}; EI-MS: m/z (%) = 446 (M$^+$, 10), 415 (96), 317 (38), 175 (68), 129 (68), 76 (44), 31 (100); NMR data for the major isomer (65%); ^{1}H NMR: $\delta = 1.29$ (t, $^3J = 7.2$ Hz, *Me*), 3.45 (s, O*Me*), 3.67 and 3.95 (m, CH$_2$), 3.98 (s, O*Me*), 5.80 (d, $^3J = 7.7$ Hz, CH), 6.39 (d, $^3J = 7.7$ Hz, CH), 6.89 (d, $^3J = 7.7$ Hz, CH), 7.04–7.27 (m, 5CH), 7.29 (s, CH), 7.38 (t, $^3J = 7.7$ Hz, CH), 7.44 (d, $^3J =$ 7.6 Hz, CH) ppm; ^{13}C NMR: $\delta = 12.2$ (*Me*), 34.8 (CH$_2$), 51.7, 53.5 (2O*Me*), 78.1 (C), 80.2 (CH), 105.0 (C), 105.3, 108.6 (2CH), 122.5, 123.6 (2C), 123.8, 124.4, 125.2, 127.0, 127.7, 129.6, 129.9, 130.2 (8CH), 130.4, 143.1 (2C), 144.9, 163.6, 163.9 (3C=O), 173.2 (C=O) ppm; NMR data for the minor isomer (30%); ^{1}H NMR: $\delta = 1.25$ (t, $^3J = 7.1$ Hz, *Me*), 3.52 (s, O*Me*), 3.60 and 3.75 (m, CH$_2$), 3.89 (s, O*Me*), 5.81 (d, $^3J = 7.6$ Hz, CH), 6.37 (d, $^3J = 7.6$ Hz, CH), 6.50 (s, CH), 6.77 (d, $^3J = 7.6$ Hz, CH), 7.04–7.27 (m, 5CH), 7.41 (t, $^3J = 7.7$ Hz, CH), 7.62 (d, $^3J = 7.6$ Hz, CH) ppm; ^{13}C NMR: $\delta = 12.4$ (*Me*), 35.2 (CH$_2$), 51.7, 53.5 (2O*Me*), 77.9 (C), 80.1 (CH), 105.2 (C), 105.5, 108.2 (2CH), 123.0, 123.4 (2C), 124.0, 124.4, 125.7, 127.5, 127.9, 128.8, 129.5, 130.0 (8CH), 130.5, 144.2, 145.3 (3C), 163.1, 163.5, 173.5 (3C=O) ppm.

Diethyl 1,2-dihydro-2-oxo-1-ethylspiro[3H-indole-3,2′-[2H,11bH][1,3]oxazino[2,3-a]isoquinoline]-3′,4′-dicarboxylate (**1f**, $C_{27}H_{26}N_2O_6$)

Yellow crystals, mp 102–104°C; yield 0.87 g, 92%; IR (KBr): $\bar{\nu} = 1742$, 1721, 1647, 1593, 1566 cm^{-1}; EI-MS: m/z (%) = 474 (M$^+$, 5), 429 (75), 384 (78), 176 (86), 129 (48), 104 (100), 76 (44), 45 (100); NMR data for the major isomer (62%); ^{1}H NMR: $\delta = 1.25$, 1.33, 1.41 (3t, $^3J = 7.1$ Hz, 3*Me*), 3.74 and 3.80 (m, CH$_2$), 3.82 (q, $^3J = 7.1$ Hz, OCH$_2$), 4.47 (q, $^3J = 7.1$ Hz, OCH$_2$), 5.79 (d, $^3J = 8.2$ Hz, CH), 6.42 (d, $^3J =$ 7.2 Hz, CH), 6.89 (d, $^3J = 8.2$ Hz, CH), 6.97 (t, $^3J = 7.4$ Hz,

CH), 7.01 (s, CH), 7.08–7.30 (m, 5CH), 7.35 (s, CH), 7.46 (d, $^3J = 7.5$ Hz, CH) ppm; ^{13}C NMR: $\delta = 12.5$, 13.7, 13.9 (3*Me*), 34.8 (CH_2), 60.3, 62.7 (2OCH_2), 78.0 (C), 79.4 (CH), 104.7 (C), 104.9 (CH), 108.3 (CH), 122.8 (C), 123.2 (C), 123.6 (CH), 125.1 (CH), 125.9 (CH), 126.2 (CH), 127.1 (CH), 128.1 (CH), 129.5 (CH), 129.9 (CH), 130.1 (C), 145.1 (C), 145.6 (C), 163.1 (C=O), 163.2 (C=O), 174.3 (C=O) ppm; NMR data for the minor isomer (28%); ^{1}H NMR: $\delta = 0.82$, 0.86, 0.89 (3t, $^3J = 7.2$ Hz, 3*Me*), 3.70 and 3.85 (m, CH_2), 3.92 (q, $^3J = 7.1$ Hz, OCH_2), 4.50 (q, $^3J = 7.2$ Hz, OCH_2), 5.81 (d, $^3J = 8.2$ Hz, CH), 6.46 (d, $^3J = 7.2$ Hz, CH), 6.50 (s, CH), 6.97 (d, $^3J = 8.2$ Hz, CH), 7.01 (t, $^3J = 7.4$ Hz, CH), 7.08–7.30 (m, 5CH), 7.39 (d, $^3J = 7.5$ Hz, CH) ppm; ^{13}C NMR: $\delta = 12.3$, 13.6, 13.8 (3*Me*), 35.3 (CH_2), 60.5, 62.8 (2OCH_2), 77.4 (C), 80.1 (CH), 104.9 (C), 105.1, 108.4 (2CH), 122.4, 122.7 (2C), 123.9, 124.5, 125.1, 126.9, 127.8, 128.9, 129.6, 130.2 (8CH), 131.2, 143.2, 144.4 (3C), 163.0, 163.3, 174.0 (3C=O) ppm.

Dimethyl 1,2-dihydro-1,3-dioxospiro[3H-indene-3,2′-[2H,11bH][1,3]oxazino[2,3-a]isoquinoline]-3′,4′-dicarboxylate (**7**, $C_{24}H_{17}NO_7$)
Yellow crystals, mp 210–212°C; yield 0.80 g, 93%; IR (KBr): $\bar{\nu} = 1730$, 1725, 1695 cm^{-1}; EI-MS: m/z (%) = 431 (M^+, 15), 416 (25), 369 (44), 302 (78), 160 (96), 129 (48), 104 (100), 76 (44), 31 (100); ^{1}H NMR: $\delta = 3.47$, 3.99 (2s, 2O*Me*), 5.86 (d, $^3J = 7.8$ Hz, CH), 6.41 (d, $^3J = 7.8$ Hz, CH), 6.77 (s, CH), 7.11 (d, $^3J = 7.6$ Hz, CH), 7.15–7.96 (m, 5CH), 8.02 (d, $^3J =$ 7.2 Hz, CH), 8.11 (d, $^3J = 7.5$ Hz, CH) ppm; ^{13}C NMR: $\delta = 52.0$, 53.5 (2O*Me*), 79.7 (C), 80.9 (CH), 104.0 (C), 105.6, 123.6 (2CH), 123.9, 124.5 (2C), 125.4 (CH), 125.5 (2CH), 127.1, 127.9 (2CH), 129.8 (C), 136.0 (CH), 136.3 (2CH), 141.8 (2C), 163.0, 163.9 (2C=O), 190.8 (2C=O) ppm.

Dimethyl 1,2-dihydro-1,3-dioxospiro[3H-indene-3,3′-[3H,4aH][1,3]oxazino[3,2-a]quinoline]-1,2-dicarboxylate (**8**, $C_{24}H_{17}NO_7$)
Yellow crystals, mp 190–192°C; yield 0.65 g, 75%; IR (KBr): $\bar{\nu} = 1740$, 1727, 1694 cm^{-1}; EI-MS: m/z (%) = 431 (M^+, 10), 416 (65), 369 (78), 178 (54), 129 (48), 104 (100), 76 (44), 31 (100); ^{1}H NMR: $\delta = 3.72$, 3.86 (2s, 2O*Me*), 6.44 (d, $^3J = 7.8$ Hz, CH), 6.81 (d, $^3J = 7.8$ Hz, CH), 6.87 (s, CH), 6.94 (d, $^3J = 7.6$ Hz, CH), 6.95 (d, $^3J = 7.6$ Hz, CH), 7.11 (d, $^3J = 7.6$ Hz, CH), 7.71 (d, $^3J = 7.6$ Hz, CH), 7.78 (t, $^3J =$ 7.5 Hz, 2CH), 7.98 (d, $^3J = 7.6$ Hz, 2CH) ppm; ^{13}C NMR: $\delta = 51.4$, 52.2 (2O*Me*), 85.1 (CH), 89.7, 109.1 (2C), 117.3, 120.1, 121.9 (3CH), 124.8 (2CH), 125.4, 128.6 (2CH), 129.1 (C), 131.5 (CH), 134.3 (2CH), 138.8 (C), 140.3 (2C), 151.4 (C), 163.0, 163.9 (2C=O), 190.8 (2C=O) ppm.

Dimethyl 1,2-dihydro-1,3-dioxospiro[3H-indene-3,2′-[2H,9aH]pyrido[2,1-b][1,3]oxazino]-3,4-dicarboxylate (**9**, $C_{20}H_{15}NO_7$)
Yellow crystals, mp 154–156°C; yield 0.64 g, 84%; IR (KBr): $\bar{\nu} = 1735$, 1730, 1685 cm^{-1}; EI-MS: m/z (%) = 381 (M^+, 15), 350 (85), 316 (44), 144 (54), 76 (44), 31 (100); ^{1}H NMR: $\delta = 3.64$, 3.68 (2s, 2O*Me*), 5.89 (d, $^3J = 7.8$ Hz, CH), 6.15 (d, $^3J = 7.8$ Hz, CH), 6.25 (d, $^3J = 7.6$ Hz, CH), 6.52 (s, CH), 7.32 (t, $^3J = 7.2$ Hz, 2CH), 7.41 (d, $^3J = 7.2$ Hz, 2CH), 8.11 (d, $^3J = 7.5$ Hz, CH) ppm; ^{13}C NMR: $\delta = 51.7$, 53.5 (2O*Me*), 76.9 (CH), 97.9, 107.5 (2C), 109.2, 109.9 (2CH), 122.3 (2CH), 133.1 (CH), 135.4 (2CH), 136.8 (CH), 138.6 (2C), 149.8 (C), 163.0, 163.9 (2C=O), 190.8 (2C=O) ppm.

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