

PHENANTHRIDINIUM-BASED AZOMETHINE YLIDES IN 1,3-DIPOLAR CYCLOADDITION WITH DIMETHYL ACETYLENEDICARBOXYLATEMilan POTACEK^{a,*}, Tomas TOPINKA^a, Jiri DOSTAL^b and Jaromir MAREK^c^a Department of Organic Chemistry,
Masaryk University, 611 37 Brno, The Czech Republic^b Department of Biochemistry,
Masaryk University, 662 43 Brno, The Czech Republic^c Department of Inorganic Chemistry,
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Dedicated to Professor Milan Kratochvil on the occasion of his 70th birthday.

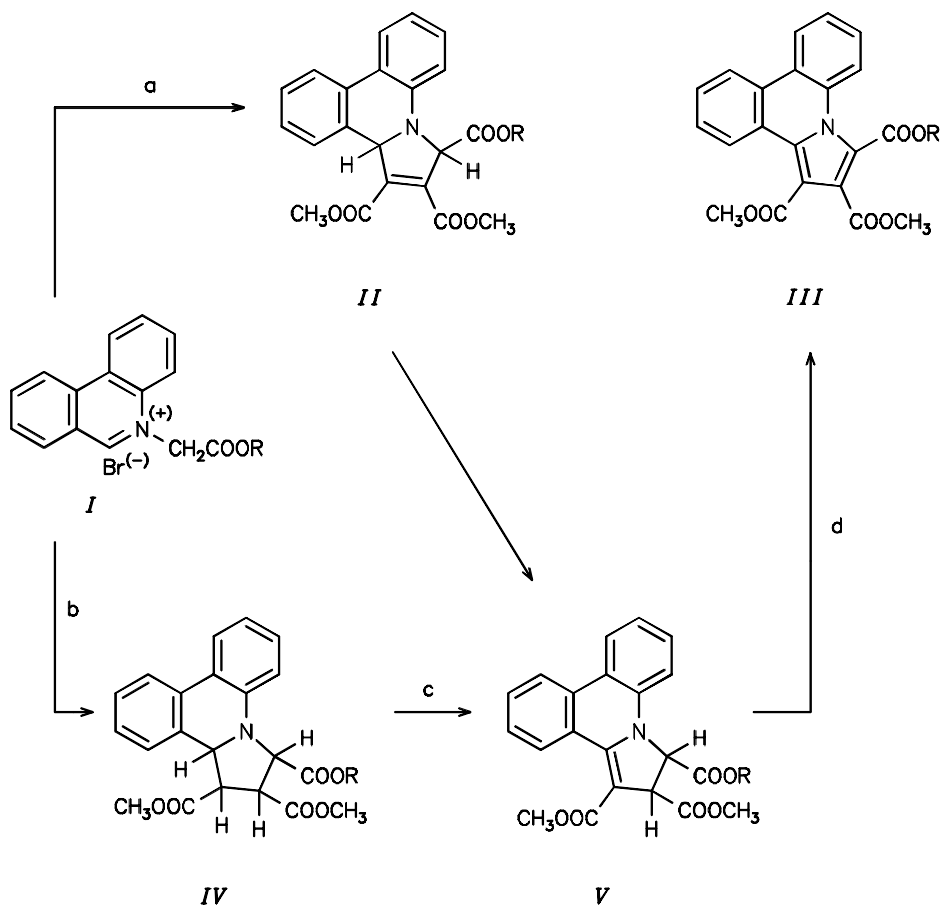
Azomethine ylides generated from 5-(alkoxycarbonylmethyl) phenanthridinium cations *I* were used in the 1,3-dipolar cycloadditions with dimethyl acetylenedicarboxylate as dipolarophile. The cycloadducts *II* were found to be very unstable species and readily oxidized to fully aromatic pyrrolo[1,2-*f*]phenanthridines *III*. Their structure was compared with the compounds formed by the oxidation of cycloadducts *IV* of the same ylide with dimethyl fumarate and maleate. In both cases pyrrolines *V* were found as intermediates. The structure of the products was determined by NMR and MS as well as by X-ray analysis.

Azomethine ylides as 1,3-dipoles in cycloaddition reactions were found to be useful for preparation of five-membered nitrogen heterocycles¹. Pyridinium, imidazolinium, isoquinolinium and 3,4-dihydroisoquinolinium cations were described as a source of these ylides²⁻⁵. Recently we have studied reactions of azomethine ylides derived from 5-(alkoxycarbonylmethyl)phenanthridinium with dimethyl maleate and fumarate⁶. Now we report on cycloadditions of the same ylides with dimethyl acetylenedicarboxylate (Scheme 1).

EXPERIMENTAL

Melting points were determined on a Kofler hot-stage Rapido 79-2106 and are uncorrected. Elemental analyses were performed with an elemental analyser Perkin-Elmer 2400. TLC was car-

* The author to whom correspondence should be addressed.



In formulae *I* – *V* : *a*, R = CH₃; *b*, R = C₂H₅

a) (C₂H₅)₃N, dimethyl acetylenedicarboxylate; *b*) (C₂H₅)₃N, dimethyl maleate/fumarate, ref.⁶; *c*) oxidation, ref.⁶; *d*) oxidation

SCHEME 1

ried out on Silufol UV 254 (Kavalier, Votice, The Czech Republic) in ether, detection in UV light (254 nm). Infrared spectra were measured on a Unicam SP 1000 spectrometer in KBr pellets (wave-numbers in cm^{-1}). ^1H and ^{13}C NMR spectra (δ , ppm; J , Hz) were measured in CDCl_3 on a Tesla BS 587 A spectrometer (80/20 MHz) with TMS as an internal standard. Mass spectra were recorded on a Varian Mat 445 spectrometer. Phenanthridine and dimethyl acetylenedicarboxylate were products of Janssen Chimica. Organic solvents were dried prior to use. The preparation and physico-chemical data of the phenanthridinium salts *Ia*, *Ib* are published in our previous communication⁶.

X-Ray Structure Determination

Structure of the compound *IIIa* was solved by direct methods using SHELXS86 (ref.⁷) and refined on F2 for all reflections using SHELXL93 (ref.⁸). Data collection and structure refinement parameters are summarized in Table I. Crystals of the compound *IIIa* are orthorhombic with space group *Pbca*. $V = 3\,742.2(35)\text{ \AA}^3$, $Z = 8$, $D_{\text{calc}} = 1.389\text{ g cm}^{-3}$.

1,2,3-Trimethyl pyrrolo[1,2-*f*]phenanthridine-1,2,3-tricarboxylate (*IIIa*)

Compound *Ia* (0.66 g, 2 mmol) and dimethyl acetylenedicarboxylate (0.29 g, 2 mmol) were suspended in dried dichloromethane. After the nitrogen atmosphere was introduced, triethylamine (0.3 g, 3 mmol) was added. Then the reaction mixture was stirred for 24 h until all the solid dissolved. The solvent was evaporated and the residue was extracted 4 times with ether (20 ml). The etheric extract was kept standing in air atmosphere for several days. The residue after removal of ether was crystallized from acetone. Yield 0.25 g (32%) of the compound *IIIa*, m.p. 216 – 218 °C. For $\text{C}_{22}\text{H}_{17}\text{NO}_6$ (391.4) calculated: 67.51% C, 4.38% H, 3.58% N; found: 67.70% C, 4.35% H, 3.60% N. IR spectrum: 3 040, 2 960, 2 930, 2 900, 2 880, 2 860, 1 720 (CO), 1 715 (CO), 1 595, 1 530, 1 490, 1 445, 1 270, 1 230, 1 200, 1 130, 1 020, 750, 715. ^1H NMR spectrum: 3.93 s, 4.01 s, 4.03 s, $3 \times 3\text{ H}$, ($3 \times \text{OCH}_3$); 7.38 – 8.44 m, 8 H (arom.). ^{13}C NMR spectrum: 52.42, 52.70, 53.13 ($3 \times \text{OCH}_3$), 118.36, 118.57, 121.71, 122.50, 122.82, 123.93, 124.07, 125.00 ($8 \times \text{arom.}$), 126.03, 123.28, 126.96, 128.42, 128.57, 128.67, 131.49 ($8 \times \text{C}_q$), 163.14, 164.11, 166.50 ($3 \times \text{CO}$). Mass spectrum (chemical ionization), m/z : 392 (MH^+ , 47%), 360 (100), 117 (30), 99 (10).

3-Ethyl-1,2-dimethyl pyrrolo[1,2-*f*]phenanthridine-1,2,3-tricarboxylate (*IIIb*)

Method A: The compound *IIIb* was prepared by the procedure described for the compound *IIIa*, starting from *Ib* (0.69 g, 2 mmol), yield 0.22 g (27%) of the compound *IIIb*, m.p. 180 – 181 °C. For $\text{C}_{23}\text{H}_{19}\text{NO}_6$ (405.4) calculated: 68.14% C, 4.72% H, 3.46% N; found: 68.23% C, 4.58% H, 3.46% N. IR spectrum: 3 030, 2 950, 2 920, 2 900, 2 880, 2 840, 1 730 (CO), 1 715 (CO), 1 595, 1 520, 1 490, 1 445, 1 270, 1 230, 1 200, 1 130, 1 030, 740, 710. ^1H NMR spectrum: 1.42 t, 3 H, $J = 7.2$ (CCH_3); 3.92 s, 4.00 s, $2 \times 3\text{ H}$ ($2 \times \text{OCH}_3$); 4.51 q, 2 H, $J = 7.2$ (CH_2); 7.36 – 8.45 m, 8 H (arom.). ^{13}C NMR spectrum: 13.95 (CH_3), 52.31, 52.67 ($2 \times \text{OCH}_3$), 62.45 (OCH_2), 118.57, 122.46, 124.03, 125.03, 125.96, 128.24, 128.53, 128.64 ($8 \times \text{arom.}$), 120.72, 122.07, 122.82, 123.25, 125.03, 126.96, 130.63, 131.53 ($8 \times \text{C}_q$); 162.64, 164.18, 166.50 ($3 \times \text{CO}$). Mass spectrum (electron impact), m/z : 405 (M^+ , 100%), 374 (11), 360 (16), 333 (48), 302 (59), 270 (31), 243 (31), 214 (68).

Method B: Pyrrolinophenanthridine *Vb* (ref.⁶, 0.1 g, 0.25 mmol) was dissolved in dichloromethane and the mixture was stirred for 14 days at room temperature. Then the solvent was evaporated in vacuo and the residue was crystallized from ether–cyclohexane 1 : 1. Yield 0.02 g (20%) of the compound *IIIb*.

RESULTS AND DISCUSSION

Ylides from the cations *I* were generated by triethylamine in the presence of the dipolarophile – dimethyl acetylenedicarboxylate in anhydrous dichloromethane. The formation of ylide was indicated by changing the colour to pink. The course of the reaction was monitored by gradual dissolution of the quaternary salt *I* and the change in colour to yellow. The reaction was followed by TLC and was finished within 24 h. The expected direct adducts *II* so formed had a sticky consistency and resisted to isolation because of easy oxidation by air oxygen to products *III*. Although we made attempts to purify the expected cycloadducts *II* by column chromatography on silica gel with ether, our effort was not successful. The oxidation had probably been proceeding on the column. As we deduced from the ^1H NMR spectrum of the crude reaction mixture, the first fraction we isolated contained the compound *V*. Thus, in the reaction of ylide generated from *Ia* we obtained a product, spectrum of which contained in addition to the signals of traces of aromatic pyrrolophenanthridine *IIIa* (the signals of CH_3 in methoxycarbonyl groups appeared at 3.69, 3.70 and 3.75 ppm) as well as two doublets belonging to the protons H-2 and H-3 (4.65 and 5.24 ppm, respectively, $J = 13$ Hz) in *Va*. The second fraction contained the adducts *II* as a mixture of diastereoisomers in about equal concentration. Their separation was not successful. We could identify them by ^1H NMR spectrum in the mixture only. The product with H-3, H-12b-*cis* configuration displayed signals at 5.34 and 4.47 ppm, $J(3,12b) = 9.0$ Hz and the product with H-3, H-12b-*trans* at 5.18 and 4.28 ppm, $J(3,12b) = 3.7$ Hz. The methyl groups appeared at 3.91, 3.82, 3.75 and 3.74 (doubled), 3.69, respectively. Although the spectra showed unusual long-range coupling, such interactions are in a good agreement with those in trimethyl *N*-alkyl-5-phenyl-3-pyrroline-2,3,4-tricarboxylate⁹.

Similar observations were made for ylide from *Ib*. The reaction mixture besides the fully aromatic pyrrolo[1,2-*f*]phenanthridine *IIIb* contained two doublets belonging to the *trans*-protons H-2 and H-3 (5.14 and 4.26, $J = 3.8$ Hz) and signals of CH_3O at 3.74 and 3.76 and signals of ethyl (1.22 t, 4.27 q, $J = 7.0$ Hz) in partially dehydrogenated product *Vb*. Other two doublets of H-3, H-12b – *cis*-product *II* (5.38 and 4.49, $J(3,12b) = 9.1$ Hz) accompanied the compound *Vb* in about half concentration.

When the reaction mixture of ylide from *Ib* with dimethyl acetylenedicarboxylate was maintained for a longer time, the fully aromatized compound 3-ethyl-1,2-dimethyl pyrrolo[1,2-*f*]phenanthridine-1,2,3-tricarboxylate (*IIIb*) was isolated as a main product. Similarly the ylide mentioned above with dimethyl fumarate gave after some time dehydrogenated 2,3-*trans*-3-ethyl-1,2-dimethyl 2,3-dihydropyrrolo[1,2-*f*]phenanthridine-1,2,3-tricarboxylate (*Vb*) as a main product. The compound *Vb* was sufficiently stable and well crystallizing for full characterization⁶. Pyrrolinophenanthridine *Vb* spontaneously aromatized when was exposed to air atmosphere for several days. The product was identical with the compound *IIIb* formed by the reaction of *Ib* ylide with dimethyl

acetylenedicarboxylate (Scheme 1). It means that a very rapid [1,3] sigmatropic rearrangement of *II* preceded formation of *Vb*.

We should state here a significant difference in the reactivity of compounds with different groups in position 3 towards dehydrogenation. In all the cases compounds with ethoxycarbonylmethyl group were more sensitive to oxidation than those possessing methoxycarbonylmethyl groups.

The structure of aromatic compounds *III* was proven by MS, elemental analysis, IR, ^1H and ^{13}C NMR spectra and the structure of the compound *IIIa* was confirmed by

TABLE I
Data collection and structure refinement parameters for the compound *IIIa*

Diffractometer	KUMA KM-4
Scan technique	$\omega/2\theta$
Number and 2θ range of reflections for lattice parameters refinement	25; 12 – 23°
Standard reflections and their intensity fluctuation	3 after every 200 measured fluctuation bellow 1%
Temperature	296(2) K
Wavelength	0.71073 Å
Unit cell dimensions	$a = 8.094(2)$ Å $b = 18.046(13)$ Å $c = 25.620(14)$ Å
Absorption coefficient	0.102 mm ⁻¹
$F(000)$	1 632
Crystal size	0.40 × 0.20 × 0.20 mm
θ range for data collection	2.26 to 26.07°
Index ranges	$0 \leq h \leq 10, 0 \leq k \leq 22, -31 \leq l \leq 0$
Reflections collected	3 685
Independent reflections	3 685
Refinement method	Full-matrix least-squares on F^2
Data/restraints/parameters	3 654/0/273
Goodness-of-fit on F^2	0.767
Final R indices [$I > 2 \sigma(I)$]	$R1 = 0.0378, wR2 = 0.0745$
R indices (all data)	$R1 = 0.2576, wR2 = 0.1573$
Largest diff. peak and hole	0.195, -0.206 e Å ⁻³

TABLE II

Atomic coordinates ($\cdot 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \cdot 10^3$) for non-H atoms in the compound *IIIa*; U_{eq} is defined as one third of the trace of the orthogonalized U_{ij} tensor

Atom	<i>x</i>	<i>y</i>	<i>z</i>	U_{eq}
C1	1503(5)	1391(2)	3787(1)	51(1)
C2	946(5)	2039(2)	4014(1)	51(1)
C3	477(5)	2537(2)	3620(1)	47(1)
N4	777(4)	2176(2)	3151(1)	58(1)
C4A	404(4)	2405(2)	2614(1)	42(1)
C5	-491(5)	3041(2)	2506(2)	55(1)
C6	-792(5)	3262(2)	1999(2)	63(1)
C7	-195(6)	2832(2)	1591(2)	70(1)
C8	644(5)	2187(2)	1693(2)	64(1)
C8A	975(5)	1954(2)	2208(1)	49(1)
C8B	1846(5)	1259(2)	2319(1)	48(1)
C9	2493(5)	812(2)	1924(2)	62(1)
C10	3277(6)	154(2)	2030(2)	67(1)
C11	3455(5)	-71(2)	2543(2)	64(1)
C12	2865(5)	357(2)	2944(2)	59(1)
C12A	2028(5)	1024(2)	2839(1)	43(1)
C12B	1446(4)	1482(2)	3249(1)	34(1)
C13	2137(6)	749(2)	4090(2)	61(1)
C14	1572(7)	-422(2)	4445(2)	108(2)
C15	916(6)	2168(2)	4589(1)	59(1)
O19	3479(5)	733(2)	4297(1)	104(1)
O20	1043(4)	214(1)	4118(1)	72(1)
O21	654(5)	1705(2)	4903(1)	103(1)
O22	1330(4)	2860(2)	4708(1)	75(1)
O23	652(4)	3849(1)	3533(1)	79(1)
O24	-1308(4)	3356(2)	4035(1)	74(1)
C16	1276(7)	3056(2)	5259(1)	92(2)
C17	-33(5)	3319(2)	3708(1)	52(1)
C18	-1705(6)	4101(2)	4223(2)	103(2)

TABLE III
Selected bond lengths (Å) for the compound *IIIa*

Atoms	Distances	Atoms	Distances
C1–C2	1.381(5)	C8B–C9	1.396(5)
C1–C12B	1.388(4)	C8B–C12A	1.406(4)
C1–C13	1.486(5)	C9–C10	1.373(5)
C2–C3	1.403(5)	C10–C11	1.383(5)
C2–C15	1.493(5)	C11–C12	1.372(5)
C3–N4	1.388(4)	C12–C12A	1.407(5)
C3–C17	1.488(5)	C12A–C12B	1.416(4)
N4–C12B	1.387(4)	C13–O19	1.209(5)
N4–C4A	1.468(4)	C13–O20	1.313(5)
C4A–C5	1.384(4)	C14–O20	1.484(4)
C4A–C8A	1.400(5)	C15–O21	1.180(4)
C5–C6	1.382(5)	C15–O22	1.329(4)
C6–C7	1.388(5)	O22–C16	1.457(4)
C7–C8	1.372(5)	O23–C17	1.194(4)
C8–C8A	1.411(5)	O24–C17	1.330(4)
C8A–C8B	1.467(5)	O24–C18	1.463(5)

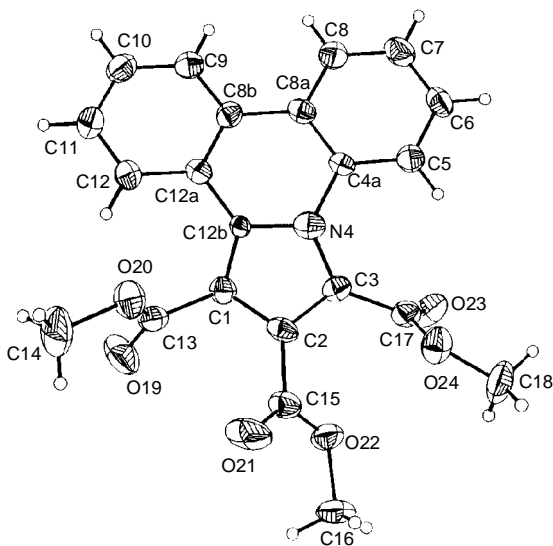


FIG. 1
A perspective view of molecule *IIIa* with atom numbering

X-ray analysis (Tables I – IV). The molecule is planar due to highly conjugated system within all the four rings (Fig. 1). In the pyrrole ring all the bonds have almost the same length, forming in such a way a regular pentagon. The interaction between the parallel molecules occurs only through the van der Waals contacts.

TABLE IV
Selected angles (°) in the compound *IIIa*

Atoms	Angles	Atoms	Angles
C2–C1–C12B	107.9(3)	C12A–C8B–C8A	119.5(3)
C2–C1–C13	123.6(3)	C10–C9–C8B	122.0(4)
C12B–C1–C13	128.4(3)	C9–C10–C11	119.3(4)
C1–C2–C3	109.1(3)	C12–C11–C10	120.6(4)
C1–C2–C15	123.6(3)	C11–C12–C12A	120.4(4)
C3–C2–C15	127.3(4)	C8B–C12A–C12	119.3(3)
N4–C3–C2	105.9(3)	C8B–C12A–C12B	119.5(3)
N4–C3–C17	128.7(3)	C12–C12A–C12B	121.2(3)
C2–C3–C17	124.9(3)	N4–C12B–C1	107.4(3)
C12B–N4–C3	109.6(3)	N4–C12B–C12A	121.5(3)
C12B–N4–C4A	120.3(3)	C1–C12B–C12A	131.0(3)
C3–N4–C4A	130.0(3)	O19–C13–O20	124.3(4)
C5–C4A–C8A	120.4(3)	O19–C13–C1	124.0(4)
C5–C4A–N4	121.9(3)	O20–C13–C1	111.7(4)
C8A–C4A–N4	117.7(3)	O21–C15–O22	123.7(4)
C6–C5–C4A	121.3(4)	O21–C15–C2	124.5(4)
C5–C6–C7	119.1(4)	O22–C15–C2	111.6(3)
C8–C7–C6	120.2(4)	C13–O20–C14	113.9(4)
C7–C8–C8A	121.7(4)	C15–O22–C16	116.2(3)
C4A–C8A–C8	117.3(4)	C17–O24–C18	115.1(3)
C4A–C8A–C8B	120.7(3)	O23–C17–O24	123.8(4)
C8–C8A–C8B	121.9(4)	O23–C17–C3	125.0(4)
C9–C8B–C12A	118.3(4)	O24–C17–C3	111.1(3)
C9–C8B–C8A	122.2(3)		

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