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Cyclocondensations of Amidophenacylation Products of Triphenylphosphoranylideneacetonitrile

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Abstract—When heated in polyphosphoric acid, the products of amidophenacylation of the available triphenylphosphoranylideneacetonitrile undergo the Robinson–Gabriel cyclization followed by other transformations. Treatment of the resulting mixture with sodium perchlorate gave quaternary phosphonium salts of two types, viz. (2,5-diaryl-1,3-oxazol-4-ylmethyl)triphenylphosphonium perchlorates and [2-aryl-5-hydroxynaphtho[2,1-*d*][1,3]oxazol-4-yl]triphenylphosphonium perchlorates. The first of these products was identified by alkaline dephosphorylation, and the structure of one of the representatives of the second class of compounds was established by X-ray diffraction.

Continuing systematic studies on phosphonium ylides with nitrogen-containing groups which are important for subsequent heterocyclizations [1–8], we turned to the reactions of triphenylphosphoranylideneacetonitrile (**I**) with amidophenacylating agents **II**, that gave a new type of polyfunctionalyzed organophosphorus substrates **III**. For the sake of simplicity, the latter products are depicted in the scheme as nonpolar phosphinomethylene structures, even though actually they are typical stabilized phosphonium ylides with an essential contribution of polar mesomeric forms. Along with the ylide bond, they all contain acylamine residues and cyano and benzoyl groups, which agrees with their IR spectra.

Heating of substrates **III** in polyphosphoric acid is likely to initially involve the Robinson–Gabriel cyclization (cf. [9]) followed by acid hydrolysis of the cyano group. As shown in the scheme, intermediate acids **IV** are stabilized via decarboxylation or cyclocondensation like the Friedel–Crafts reaction. By treatment with sodium perchlorate, the obtained mixture could separated by fractional crystallization from polar solvents to isolate pure two types of quaternary phosphonium salts of two types: [(2,5-diaryl-1,3-oxazol-4-yl)methyl]triphenylphosphonium perchlorates **V** and (2-aryl-5-hydroxynaphtho[2,1-*d*][1,3]oxazol-4-yl)triphenylphosphonium perchlorates **VI** (Table 1).

Table 1. Constants, yields, and elemental analyses of the synthesized compounds

Comp. no.	Yield, %	mp, °C (solvent for crystallization)	Found, %				Formula	Calculated, %			
			C	H	N	P		C	H	N	P
IIIa	90	220–222 (decomp.) (ethanol)	78.21	4.98	5.03	5.65	$C_{35}H_{27}N_2O_2P$	78.05	5.05	5.20	5.75
IIIb	92	172–173 (nitromethane)	78.07	5.37	4.96	5.72	$C_{36}H_{29}N_2O_2P$	78.25	5.29	5.07	5.60
Va	31	225–226 (acetonitrile–	68.83	4.50	2.22	5.13	$C_{34}H_{27}ClNO_5P$	68.52	4.57	2.35	5.20
Vb[a]	34	diethyl ether, 3 : 1)	68.73	4.73	2.40	5.25	$C_{35}H_{29}ClNO_5P$	68.91	4.79	2.30	5.08
VIa	37	194–195 (ethanol)	67.80	4.15	2.35	4.97	$C_{35}H_{25}ClNO_6P$	67.58	4.05	2.25	4.98
VIb	43	274–275 (decomp.) (ethanol)	67.79	4.28	2.23	5.01	$C_{36}H_{27}ClNO_6P$	67.98	4.28	2.20	4.87
VIIa[b]	76	312–315 (nitromethane)	81.77	5.44	6.02	–	$C_{16}H_{13}NO$	81.68	5.57	5.95	–
VIIb	80	80–81 (ethanol)	81.73	5.94	5.48	–	$C_{17}H_{15}NO$	81.90	6.06	6.62	–
VIII	85	88–90 (ethanol) 145–146 (ethanol)	80.53	4.74	2.53	5.57	$C_{36}H_{26}NO_2P$	80.73	4.89	2.62	5.78

[a] Compound **Vb** was crystallized twice. [b] Compound **VIIa** was prepared previously by another procedure [10].

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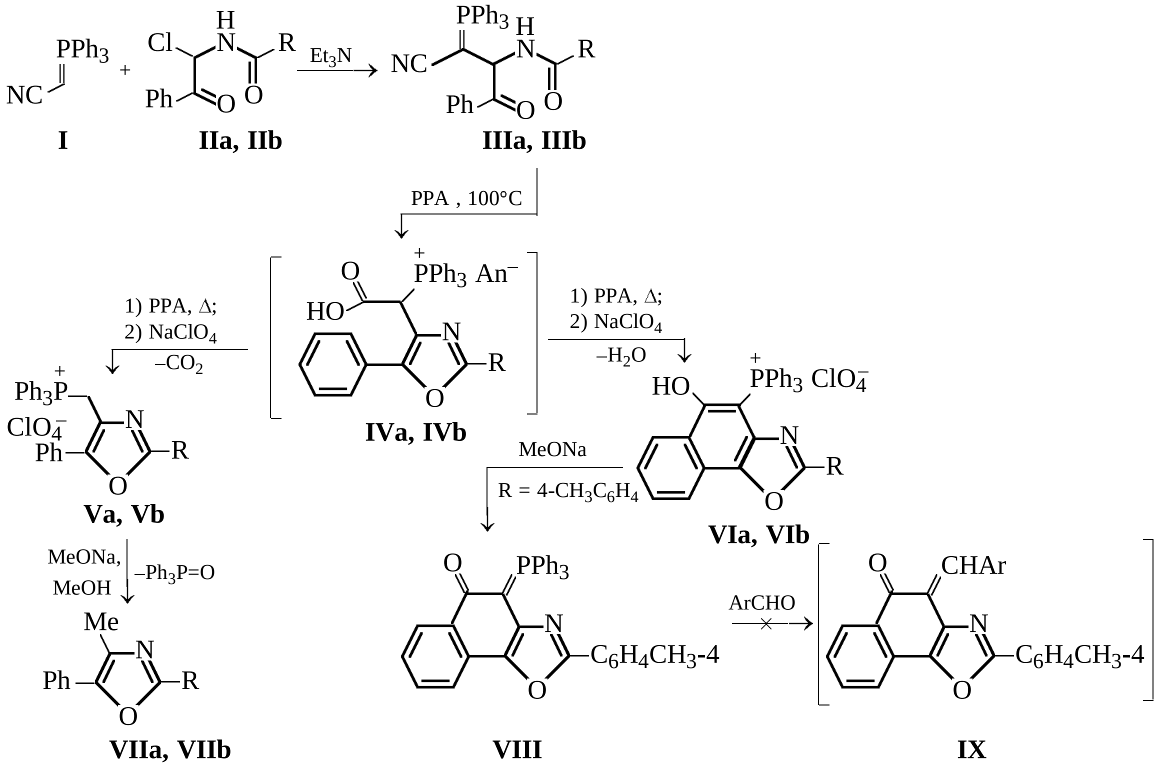


R = C_6H_5 (**a**), 4-$CH_3C_6H_4$ (**b**); Ar = ClC_6H_4, 4-$O_2NC_6H_4$; PPA is polyphosphoric acid.

The IR spectra of compounds **V** show no strong absorption bands in the range 1610–1800 and 2050–2200 cm^{-1}, which points to the absence in these products of the amido and cyano groups present in starting substrates **III**. Furthermore, from the ^1H NMR spectra we could obtain evidence for the presence of the $-CH_2\overset{+}{P}<$ group. Finally, treatment of these phosphonium salts with sodium methylate in methanol produces cleavage of the P–C bond to form the corresponding 2,5-diaryl-4-methyl-1,3-oxazoles. One of them (R=Ph) was prepared previously by another procedure [10]. At the same time, for unambiguous structural assessment of compounds **VI** we made use of X-ray diffraction analysis. The general view of molecule **VIb** is shown in the figure, and its principal geometric parameters and atomic coordinates are listed in Tables 2 and 3, respectively.

The O^1NC^{1-11} tricyclic system is roughly planar within 0.116 Å. Therewith, the O^1NC^{1-3}, $C^{2-4,9-11}$, and C^{4-9} rings are planar within 0.006, 0.036, and 0.016 Å, respectively. The O^1NC^{1-3} and C^{4-9} rings form with the central $C^{2-4,9-11}$ ring dihedral angles of 3.0 and 4.6°. The C^{12-17} benzene ring is almost coplanar to the tricyclic system (the corresponding dihedral angle is as little as 7.8°). Geometric parameters of the triphenylphosphonium group are normal [11, 12]. An interesting peculiarity of the crystal structure

Table 2. Principal bond lengths (*d*, Å) and bond angles (ω, deg) in **VIb**

Bond	*d*	Angle	ω
$P–C^{11}$	1.781(6)	$C^{11}PC^{25}$	113.2(3)
$P–C^{25}$	1.788(6)	$C^{11}PC^{19}$	108.0(3)
$P–C^{19}$	1.788(6)	$C^{25}PC^{19}$	110.5(3)
$P–C^{31}$	1.791(6)	$C^{11}PC^{31}$	108.9(3)
$O^1–C^1$	1.375(7)	$C^{25}PC^{31}$	107.0(3)
$O^1–C^3$	1.376(7)	$C^{19}PC^{31}$	109.3(3)
$O^2–C^{10}$	1.385(7)	$C^1O^1C^3$	103.7(4)
$N–C^1$	1.299(7)	C^1NC^2	104.3(5)
$N–C^2$	1.391(7)	NC^1O^1	114.5(5)
$C^1–C^{12}$	1.447(8)	C^3C^2N	109.3(5)
$C^2–C^3$	1.362(8)	$C^3C^2C^{11}$	119.9(5)
$C^2–C^{11}$	1.423(8)	$C^2C^3O^1$	108.1(5)
$C^3–C^4$	1.398(8)	$C^2C^3C^4$	125.7(5)
$C^4–C^5$	1.406(8)	$C^3C^4C^9$	115.3(5)
$C^4–C^9$	1.417(8)	$C^5C^4C^9$	119.8(5)
$C^5–C^6$	1.359(10)	$C^6C^5C^4$	119.9(6)
$C^6–C^7$	1.396(10)	$C^5C^6C^7$	120.5(6)
$C^7–C^8$	1.360(9)	$C^8C^7C^6$	120.9(6)
$C^8–C^9$	1.407(8)	$C^7C^8C^9$	120.4(6)
$C^9–C^{10}$	1.441(8)	$C^8C^9C^4$	118.4(5)
$C^{10}–C^{11}$	1.387(8)	$C^4C^9C^{10}$	119.5(5)
		$C^{11}C^{10}C^9$	122.8(5)
		$C^{10}C^{11}C^2$	116.5(5)

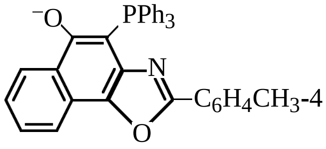
Table 3. Atomic coordinates ($\times 10^4$) and equivalent isotropic (isotropic for hydrogen atoms) thermal parameters U_{eq} ($E^2 \times 10^3$) in **VIb**

Atom[a]	*x*	*y*	*z*	U_{eq}	Atom[a]	*x*	*y*	*z*	U_{eq}
P	4614(2)	5910(1)	6774(2)	46(1)	C^{13}	7709(6)	7263(2)	3964(6)	60(2)
Cl	557(2)	6120(1)	11836(2)	72(1)	C^{14}	8563(7)	7474(2)	3151(7)	66(2)
O^1	5317(4)	7513(1)	6512(4)	51(1)	C^{15}	8705(6)	7915(2)	3200(7)	61(2)
O^2	3244(5)	6154(1)	9100(5)	64(1)	C^{16}	7984(7)	8142(2)	4096(7)	68(2)
O^{3A}	–510(15)	6400(6)	11629(15)	143(8)	C^{17}	7123(7)	7935(2)	4920(7)	63(2)
O^{4A}	1673(18)	6317(7)	12475(18)	196(12)	C^{18}	9606(8)	8150(3)	2286(8)	84(2)
O^{5A}	968(19)	6037(4)	10527(12)	135(7)	C^{19}	2250(6)	5676(2)	6638(6)	51(2)
O^{6A}	183(17)	5734(3)	12349(21)	147(9)	C^{20}	1854(7)	5920(3)	6157(8)	76(2)
O^{3B}	–664(19)	5976(12)	11334(28)	167(15)	C^{21}	575(8)	5749(3)	6069(10)	98(3)
O^{4B}	431(35)	6544(4)	1213(33)	151(15)	C^{22}	361(9)	5328(4)	6432(11)	103(3)
O^{5B}	1822(15)	6072(7)	11290(24)	85(9)	C^{23}	1424(10)	5090(3)	5890(11)	107(3)
O^{6B}	800(25)	5918(12)	13071(20)	187(20)	C^{24}	2729(8)	5255(3)	6998(9)	82(2)
N	5934(5)	6854(2)	5843(5)	48(1)	C^{25}	5757(6)	5577(2)	7762(7)	55(2)
C^1	6805(6)	7267(2)	5709(6)	49(2)	C^{26}	6274(9)	5707(3)	8977(8)	84(2)
C^2	5010(5)	6814(2)	6821(5)	43(1)	C^{27}	7788(12)	5446(3)	9687(10)	125(4)
C^3	4646(6)	7213(2)	7230(6)	45(1)	C^{28}	7563(11)	5061(3)	9214(10)	110(3)
C^4	3739(6)	7301(2)	8205(6)	47(1)	C^{29}	7047(9)	4924(3)	8002(10)	90(3)
C^5	3288(7)	7714(2)	8539(7)	59(2)	C^{30}	6158(8)	5181(2)	7265(8)	76(2)
C^6	2370(8)	7761(2)	9476(7)	70(2)	C^{31}	5269(6)	5941(2)	5166(6)	49(1)
C^7	1903(7)	7402(2)	1147(7)	70(2)	C^{32}	4423(7)	6014(2)	4057(7)	66(2)
C^8	2342(7)	7000(2)	9865(7)	61(2)	C^{33}	4973(10)	6085(3)	2850(8)	87(2)
C^9	3247(6)	6935(2)	8861(6)	48(1)	C^{34}	6351(10)	6078(3)	2757(8)	83(2)
C^{10}	3652(6)	6511(2)	8461(6)	48(2)	C^{35}	7196(9)	6000(3)	3845(9)	83(2)
C^{11}	4466(6)	6441(2)	7413(6)	45(1)	C^{36}	6665(7)	5933(3)	5042(7)	70(2)
C^{12}	6973(6)	7494(2)	4859(6)	52(2)	H^2	2576(83)	6180(27)	9539(83)	88(29)

[a] The O^3, O^4, O^5, and O^6 atoms are distributed over two positions (A and B) with occupancies of 0.65 and 0.35, respectively.

of compound **VIb** is an O–H···O hydrogen bond. The hydroxy group of this bond belongs to the cation, while the oxygen atom, to the perchlorate anion. The principal geometric parameters of the hydrogen bond are as follows: $O^2\cdots O^{5A}$ 2.764(8), $O^2\cdots O^{5B}$ 2.708(8), and $O^2–H^2$ 0.82(8) Å; $O^2H^2O^{5A}$ 161(6) and $O^2H^2O^{5B}$ 145(6)°.

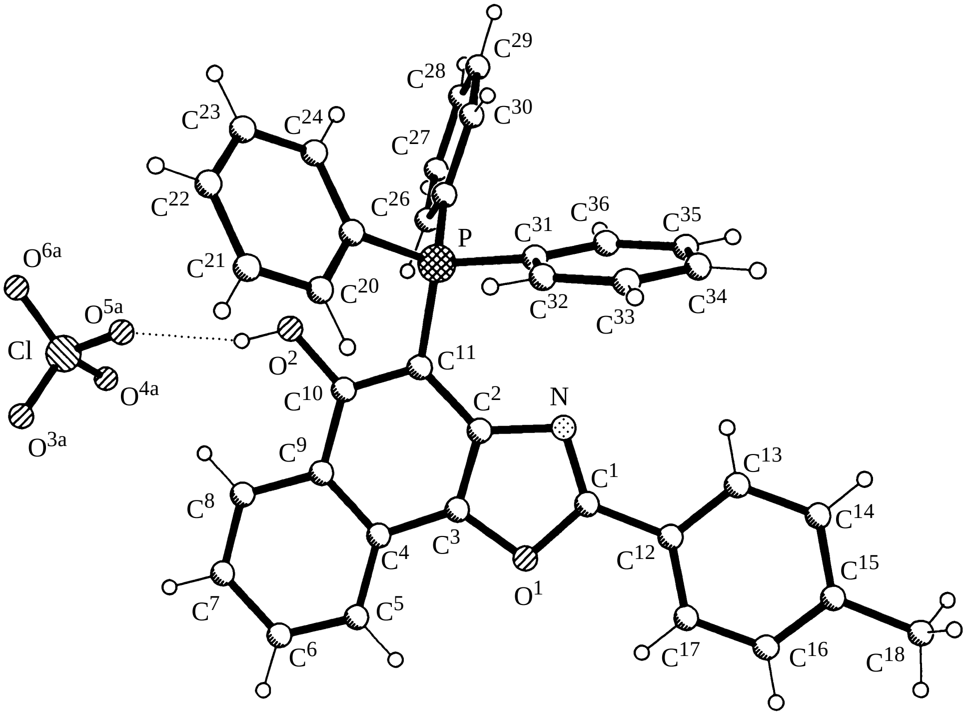
Treatment of phosphonium salt **VIb** with sodium methylate leads to formation of a superstabilized phosphonium ylide **VIII** which does not enter the Wittig reaction with aromatic aldehydes even under rigid conditions. Therefore, the phosphinomethylene and ylide structures of compound **VIII** are unlikely to contribute more than the mesomeric betaine structure presented below.



EXPERIMENTAL

The IR spectra were recorded on a UR-20 spectrometer in KBr pellets and a Specord IR-71 spectrometer for 0.1 M solutions in CH_2Cl_2. The ^1H NMR spectra were measured on a Varian VXR-300 spectrometer in DMSO-d_6 against TMS. The yields, constants, and elemental analyses of the synthesized compounds are listed in Table 1.

X-ray diffraction analysis of a single crystal of compound **VIb** with the linear dimensions $0.27 \times 0.32 \times 0.40$ mm was carried out at room temperature on an Enraft–Nonius CAD-4 automatic four-circle diffractometer (CuK_α radiation: graphite monochromator, $\omega/2\theta$ 1.2; θ_{max} 60°; index ranges $0 < h < 11$, $0 < k < 34$, and $-10 < l < 11$). A total of 4881 reflections was collected, 4587 of which were unique (R_{int} 0.60). Crystals of compound **VIb** are monoclinic, *a* 9.835(2), *b* 31.048(6), *c* 10.138(2) Å, β 93.54(3)°, *V* 3089.8(11) Å^3, *Z* 4, d_{calc} 1.367 g cm^{-3}, μ 1.990 mm^{-1}, *F*(000) 1320, space group $P2_1/c$ (no. 14). The struc-



General view of compound **VIb**.

ture was solved by the direct method [13] and refined by full-matrix least squares [14] in anisotropic approximation. Refinement was carried out on the basis of 4129 reflections with $I > 2\sigma(I)$ {448 refined parameters, number of reflections per parameter 9.2, weight scheme $\omega = 1/[\sigma^2(Fo^2) + (0.0824P)^2 + 0.6285P]$, where $P = (Fo^2 + 2Fc^2)/3$}. Correction for anomalous scattering was included, while absorption corrections were not included. All hydrogen atoms were located from difference synthesis of electron density and included in the calculation with fixed positional and thermal parameters. The H^2 atom that is involved in hydrogen bonding was refined isotropically. The final divergence factors were $R_1(F)$ 0.050 and $R_W(F^2)$ 0.138, *GOF* 1.118. The residual electron density from the differential Fourier series after the final refinement cycle is 0.42 and –0.27 e/E^3.

3-Acylamino-3-benzoyl-2-triphenylphosphoranylidenepropionitriles IIIa and IIIb. To a suspension of 10 mmol of compound **IIa** or **IIb** in 30 ml of acetonitrile, 10 ml of triethylamine was added. The resulting mixture was kept for 5 min, a suspension of 10 mmol of triphenylphosphoranylideneacetonitrile in 40 ml of acetonitrile was added, and the mixture was left to stand for 12 h. The precipitate that formed was filtered off, washed with acetonitrile and water, and purified by crystallization. IR spectrum, ν, cm^{-1} (CH_2Cl_2): compound **IIIa**: 1650 (C=O), 1675 (C=O), 2130 (C≡N), 3400 (NH); compound **IIIb**: 1650 (C=O), 1675 (C=O), 2130 (C≡N), 3400 (NH).

Triphenyl(2,5-diphenyl-1,3-oxazol-4-ylmethyl)phosphonium perchlorate (Va) and (5-hydroxy-2-phenylnaphtho[2,1-*d*][1,3]oxazol-4-yl)triphenylphosphonium perchlorate (VIa). A suspension of 6.5 mmol of compound **IIIa** in 30 ml of polyphosphoric acid was heated at 100°C for 14 h. The reaction mixture was left to stand for 12 h at 20°C, poured into 200 ml of water, stirred for 10 min, and the water was decanted. The oily residue was dissolved in 30 ml of ethanol, and 150 ml of water and 30 ml of saturated sodium perchlorate were added to the solution. The precipitate that formed was filtered off, washed with water, and dried in air, after which it was dissolved in 150 ml of boiling ethanol, and the solution was left to stand for 12 h at 20°C. Compound **Va** was filtered off and purified by crystallization. The filtrate was evaporated, and compound **VIa** was purified by crystallization. ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 7.45–7.86 m (20H, $4C_6H_5$; 2H, C^7H, C^8H), 8.215 d, 8.26 d (2H, C^6H, C^9H, $^3J_{HH}$ 8.2 Hz, $^3J_{HH}$ 8.4 Hz). No hydroxyl proton signal was found in the ^{1}H NMR spectrum of compound **VIa**.

Triphenyl(5-phenyl-2-*p*-tolyl-1,3-oxazol-4-ylmethyl)phosphonium perchlorate (Vb) and (5-hydroxy-2-*p*-tolylnaphtho[2,1-*d*][1,3]oxazol-4-yl)triphenylphosphonium perchlorate (VIb). A suspension of compound **IIIb** in 30 ml of polyphosphoric acid was heated at 100°C for 14 h. The reaction mixture was left to stand for 12 h at 20°C, poured into 200 ml of water, stirred for 10 min, and the water was decanted. The oily residue was dissolved in 30 ml of ethanol, and 150 ml of water and 30 ml of saturated sodium perchlorate were added to the solution. The precipitate that formed was filtered off, washed with water, dried in air, after which it was dissolved in 150 ml of boiling ethanol and left to stand for 12 h at 20°C. Compound **VIb** was filtered off and purified by crystallization. ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 2.36 s (3H, CH_3), 7.33 d, 7.64 d (4H, $^3J_{HH}$ 8.1 Hz, C_6H_4), 7.73–8.0 m (15H, $3C_6H_5$, 2H, C^7H, C^8H); 8.41 d, 8.44 d (2H, C^6H, C^9H, $^3J_{HH}$ 8.7 Hz, $^3J_{HH}$ 9.3 Hz), 12.00 br.s (1H, OH). The filtrate was evaporated, and compound **Vb** was purified by crystallization. ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 2.25 s (3H, CH_3); 5.48 d (2H, CH_2, $^3J_{HP}$ 15 Hz), 7.30–7.91 m (24H, $4C_6H_5$, C_6H_4).

2,5-Diphenyl-4-methyl-1,3-oxazole (VIIa). To a suspension of 0.5 mmol of compound **Va** in 5 ml of ethanol, a solution of 0.6 mmol of sodium methylate in 0.15 ml of methanol was added. The reaction mixture was left to stand for 12 h at 20°C, volatile compounds were removed in a vacuum, and the residue was treated with 2 ml of diethyl ether. The precipitate was filtered off, the filtrate was evaporated, and compound **VIIa** was purified by crystallization from ethanol. The melting point of this sample coincides with that of the authentic sample of 2,5-diphenyl-4-methyl-1,3-oxazole, obtained according to [10].

4-Methyl-5-phenyl-2-*p*-tolyl-1,3-oxazole (VIIb). To a suspension of 0.5 mmol of compound **Vb** in 5 ml of ethanol, a solution of 0.6 mmol of sodium methylate in 0.15 ml of methanol was added. The reaction mixture was left to stand for 12 h at 20°C. Compound **VIIb** precipitated and was filtered off and recrystallized.

4-Triphenylphosphoranylidene-2-*p*-tolyl-4,5-dihydronaphtho[2,1-*d*][1.3]oxazol-5-one (VIII). To a suspension of 0.4 mmol of compound **VIb** in 5 ml of absolute methanol, 0.45 mmol of sodium methylate in 12 ml of methanol was added. The reaction mixture was stirred for 2 h at 40°C. Compound **VIII** precipitated and was filtered off, washed with water, and recrystallized.

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