Novel syntheses of symmetrical 2,5-diaryl-1,3,4-oxadiazoles and 1,4-phenylenebis-1,3,4-oxadiazoles

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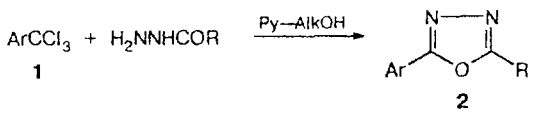
The reactions of trichloromethylarenes with excess hydrazine hydrate in ethanol gives symmetrical 2,5-diaryl-1,3,4-oxadiazoles in 68—96% yields. The reaction of 1,4-bis(trichloromethyl)benzene with acylhydrazines in an ethanol—pyridine mixture gives the corresponding substituted or unsubstituted 1,4-phenylenebis-1,3,4-oxadiazoles in 35—51% yields. The mass spectra of 2,5-diaryl-1,3,4-oxadiazoles and 1,4-phenylenebis-1,3,4-oxadiazoles were studied.

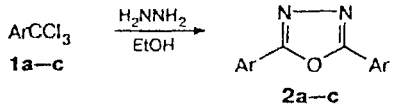
Key words: trichloromethylarenes, 2,5-diaryl-1,3,4-oxadiazoles, 1,4-phenylenebis-1,3,4-oxadiazoles.

Previously[1,2] we identified the main factors that determine the route of the reaction of trichloromethylarenes (TCMA) with acylhydrazines and thioacylhydrazines. Alcoholysis of benzotrichloride (**1a**) and its substituted derivatives in alcoholic solutions yields mostly esters of aromatic carboxylic acids, whereas the target 1,3,4-oxadiazoles (thiadiazoles) are formed as minor products. The same reaction in pyridine solutions affords reductive condensation products, *viz.*, the corresponding *N*-substituted hydrazones of aromatic aldehydes, as the major or the only products. A mixture of Py with MeOH or EtOH was found to be the best medium for conducting heterocyclization to give 1,3,4-oxadiazole (**2**) or 1,3,4-thiadiazole derivatives.



1 2

However, when the reaction of TCMA with an equivalent amount of $N_2H_4 \cdot H_2O$ is carried out in a Py—MeOH mixture, symmetrically substituted 2,5-diaryl-1,3,4-oxadiazoles were obtained in low yields (~20%); in addition to these products, the reaction gave methyl esters and hydrazides of the corresponding aromatic acids.[2] In the present study we found that the yield of 2,5-diphenyl-1,3,4-oxadiazole (**2a**) approaches a quantitative yield if Py is removed, and the reaction is carried out by refluxing in EtOH for 40 min using excess N_2H_4 to bind HCl. This result may seem unexpected, since it has been reported[3] that the reaction of benzotrichloride with $N_2H_4 \cdot H_2O$ under similar conditions (refluxing in MeOH for 5 h) gives 4-amino-3,5-diphenyltriazole. Since we did not have the original publication[3] at our disposal, we made no attempts to reproduce the results. Perhaps, the process duration played the crucial role. Anyway, our result is quite consistent with the data[4] indicating that recyclization giving 4-amino-3,5-diphenyltriazole does not occur on heating of oxadiazole **2a** with N_2H_4 for 1 h.



1a—c **2a—c**

Ar = Ph (**a**), 4-ClC_6H_4 (**b**), 3-BrC_6H_4 (**c**)

Similarly to benzotrichloride, 4-chlorobenzotrichloride (**1b**) and 3-bromobenzotrichloride (**1c**) react with N_2H_4 to give compounds **2b,c** in 81 and 68% yields, respectively. In the case of 2-chlorobenzotrichloride only the alcoholysis product, ethyl 2-chlorobenzoate (yield 78%), was isolated. Mesitotrichloride, whose transformation in pyridine—alcohol mixtures gives only products of reductive condensation, also could not be involved in heterocyclization under these conditions; instead, it was completely converted into ethyl 2,4,6-trimethylbenzoate. The attempt to prepare diphenyl-1,3,4-oxadiazole **2a** from benzotrichloride and benzohydrazide using an excess of the latter to trap HCl resulted in the target product being formed in only ~15% yield. Perhaps, benzotrichloride reacts with benzohydrazide more slowly than with $N_2H_4 \cdot H_2O$, so that alcoholysis of benzotrichloride prevails over the process yielding the heterocycle.

The reactions of TCMA with O-nucleophiles, in particular, hydrolysis and alcoholysis, occur apparently by an S_N1 mechanism. The reaction rate does not depend on an alkali or an acid added and is limited by

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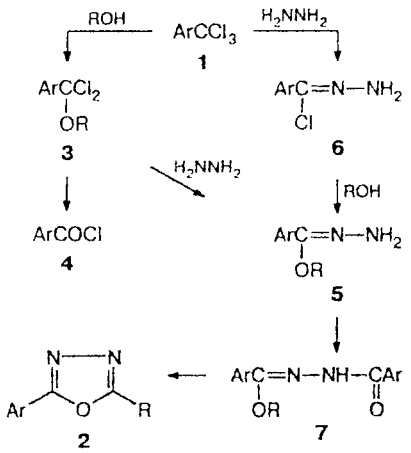
the abstraction of the Cl^- anion to give the ArC^+Cl_2 cation; the subsequent steps occur more rapidly.[5–7] It can be suggested that alcoholysis of benzotrichloride affords intermediate **3**, which is either converted into aroyl chloride **4** with abstraction of RCl (*cf.* Ref. 8) or forms a hydrazino acid ester **5**. It is also possible, as was suggested in our previous study,[2] that TCMA reacts first with hydrazine, and the resulting hydrazinoyl chloride **6** is converted into ester **5**. The latter reacts with TCMA **1**, aroyl chloride **4**, or dichloroacetal **3** to give the ester of *N*-acylhydrazino acid **7**, which is then readily converted into 2,5-diaryl-1,3,4-oxadiazole **2** (Scheme 1).

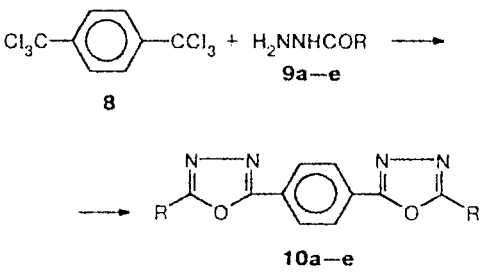
Scheme 1



Note that type **7** esters have been isolated (yields 30–50%) in the reactions of benzotrichloride with acylhydrazines[9] and with *N*-phenylsemicarbazide;[10] on heating, esters **7** were converted almost quantitatively into heterocyclization products, *viz.*, oxadiazoles of type **2**. It can be assumed that sterically hindered *o*-chlorobenzotrichloride and mesitotrichloride react predominantly with water molecules to give aroyl chlorides rather than with the alcohol or hydrazine molecules. Aroyl chlorides react with the alcohol, being thus converted into esters; as we showed previously, the latter react with hydrazine under the experimental conditions.

In this study, we extend the previously proposed procedure[1,2] to 1,4-bis(trichloromethyl)benzene (**8**). The reactions of this substrate with acylhydrazines (**9a–e**) in a mixture of Py with ethanol resulted in the synthesis of a number of 1,4-phenylenebis-1,3,4-oxadiazoles (**10a–e**) described previously (Scheme 2).

Scheme 2



R = Ph (**a**), 4-C_5H_4N (**b**), 2-HOC_6H_4 (**c**), 4-$NO_2C_6H_4$ (**d**), H (**e**)

To the best of our knowledge, no syntheses of type **10** compounds based on bis(trichloromethyl)arenes have been reported, although many systems of this type, especially those with R = Ar, possessing luminescence activity, are well known. Previously they were prepared by cyclization of the corresponding 1,4-bis(aroylhydrazino)benzenes,[11–13] aroylation of 1,4-phenylenebistetrazole[14–16] accompanied by nitrogen elimination, oxidation of bisaroylhydrazones of terephthalic aldehyde,[17] and also (to prepare compound **10e**) by thermolysis of 3-phenyl-1,2,4-triazole-1-carbaldehyde tetrephthaloylbishydrazone.[18]

Table 1. 1,4-Phenylenebis-1,3,4-oxadiazoles (**10**)

Compound	R	Reaction time /h	M.p /°C	Yield (%)	IR spectrum (in KBr), ν/cm^{-1}				References
					C_{Ar-H}	C=N	C—O—C	Other vibrations	
10a	Ph	21	309–312	35	3060	1610, 1578	1032, 1020		11,15–17
10b	4-C_5H_4N	27	337–340	41	3090, 3042	1673, 1608	1010		12[a]
10c	2-HOC_6H_4	19	352–354	38	3100	1630, 1593	1038, 1020	3180 (O—H) 1240, 1260 (C—OH)	13[b]
10d	4-$O_2NC_6H_4$	20	406–409	36	3105	1610, 1578	1019	1530, 1483 (NO_2)	14, 15
10e[c]	H	34	268–271	47	3123, 3100	1670	1018		18

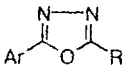
[a] No product characteristics or yields are presented in the abstract. Found (%): C, 65.47; H, 3.57; N, 23.03. $C_{20}H_{12}N_6O_2$. Calculated (%): C, 65.21; H, 3.28; N, 22.80.

[b] No product characteristics or yields are presented in the abstract. Found (%): C, 66.37; H, 3.55; N, 14.15. $C_{22}H_{14}N_4O_4$. Calculated (%): C, 66.33; H, 3.54; N, 14.07.

[c] ^1H NMR, DMSO-d_6, δ: 8.23 (s, 4 H, phenylene H); 9.39 (s, 2 H, oxadiazole H).

Despite the fact that the method proposed here gives compounds **10a—e** in relatively low yields (as in the case of diaryloxadiazoles **2**, this is due to the competing alcoholysis), it possesses a number of advantages, namely, accessibility of the initial compounds and simplicity of the procedure. Physicochemical characteristics of the compounds **10** synthesized are summarized in Table 1.

Bisoxadiazoles are poorly soluble compounds; this restricts the possibility of using NMR spectroscopy. Therefore, to prove the structures of compounds **10**, their electron impact mass spectra were recorded. Since our results did not fully confirm the data on the mass spectra of type **10** bisoxadiazoles, given in the only paper that we know,[17] and the data on the mass spectra of 2,5-disubstituted 1,3,4-oxadiazoles reported in the literature are limited to a few examples,[19—24] we also considered the mass spectra of the previously synthesized[1,2] compounds of type **2**. Data on the fragmentation of 2,5-disubstituted 1,3,4-oxadiazoles **2** are pre-

Table 2. Mass spectra of 2,5-disubstituted 1,3,4-oxadiazoles 

Ar / R	*m/z* (intensity (%))			
	$[M+1]^{+\cdot}$ / $[M]^{+\cdot}$	$[ArCO]^+$ / $[RCO]^+$	$[Ar]^+$ / $[R]^+$	Other ions
2,4,5-$Me_3C_6H_2$ / Me	203(13) / 202(100)	147(55) / 43(4)	119(9) / —	173(11) $[M-N_2-H]^+$, 160(7) $[M-CH_2CO]^{+\cdot}$, 159(15) $[M-CH_3CO]^+$, 146(24) $[M-N_2-CO]^{+\cdot}$, 132(7) $[M-CH_2CO-N_2]^{+\cdot}$, 130(9) $[C_{10}H_{10}]^{+\cdot}$, 118(11) $[Ar-H]^{+\cdot}$, 117(9) $[M-CH_2CO-N_2-CH_3]^+$ or $[C_9H_9]^+$, 105(4) $[Ar-CH_2]^{+\cdot}$, 103(6) $[M-CH_2CO-N_2-CH_3-CH_2]^+$ or $[C_8H_7]^+$, 91(13) $[PhCH_2]^+$, 77(7) $[Ph]^+$, 42(7) $[CH_2CO]^{+\cdot}$
Ph / Ph	223(14) / 222(100)	105(88)	77(69)	166(23) $[M-N_2-CO]^{+\cdot}$, 165(46) $[M-N_2-CO-H]^+$
o-HOC_6H_4 / Ph	239(21) / 238(100)	121(69) / 105(69)	93(10) / 77(41)	210(6) $[M-N_2]^{+\cdot}$, 209(7) $[M-N_2-H]^+$, 181(56) $[M-N_2-CO-H]^+$, 90(44) $[PhCH]^{+\cdot}$
o-$O_2NC_6H_4$ / Ph	268(18) / 267(100)	150(47) / 105(87)	— / 77(74)	165(24) $[C_{13}H_9]^+$, 135(44) $[C_7H_5NO_2]^{+\cdot}$, 134(62) $[(C_7H_4NO)_2]^+$, 106(49) $[C_6H_4NO]^+$, 104(53) $[C_7H_4O]^{+\cdot}$
m-$O_2NC_6H_4$ / Ph	268(23) / 267(100)	150(37) / 105(92)	— / 77(58)	165(25) $[C_{13}H_9]^+$, 104(53) $[C_7H_4O]^{+\cdot}$, 76(33) $[C_6H_4]^{+\cdot}$, 75(9) $[C_6H_3]^+$
p-$O_2NC_6H_4$ / Ph	268(22) / 267(100)	150(33) / 105(93)	— / 77(81)	165(42) $[C_{13}H_9]^+$, 104(30) $[C_7H_4O]^{+\cdot}$, 76(39) $[C_6H_4]^{+\cdot}$, 75(15) $[C_6H_3]^+$
4-C_5H_4N / Ph	224(21) / 223(100)	106(40) / 105(91)	78(25) / 77(51)	167(43) $[M-N_2-CO]^{+\cdot}$, 89(7) $[C_7H_5]^+$, 51(19) $[C_4H_3]^+$
3-C_5H_4N / Ph	224(13) / 223(91)	106(40) / 105(70)	78(23) / 77(67)	194(6) $[M-N_2+H]^{+\cdot}$, 168(12) $[MH-N_2-CO]^+$, 167(58) $[M-N_2-CO]^{+\cdot}$, 51(100) $[C_4H_3]^+$
2-Thienyl / Ph	229(13) / 228(100)	111(25) / 105(31)	83(50) / 77(25)	172(13) $[M-N_2-CO]^{+\cdot}$, 171(33) $[M-N_2-CO-H]^+$
4,5-Dibromo-2-furyl / Ph	— / 372(40), 370(100), 368(50)	255(8), 253(16), 251(8) / 105(91)	— / 77(25)	263(42) and 261(48) $[M-N_2-Br]^+$, 235(25) and 233(29) $[M-N_2-Br-CO]^+$, 126.35(75)
2,4-$Me_2C_6H_3$ / Ph	251(23) / 250(100)	133(65) / 105(56)	105(56) / 77(63)	221(70) $[M-N_2-H]^+$, 193(12) $[M-N_2-CO-H]^+$, 132(14) $[ArCO-H]^{+\cdot}$, 104(33) $[Ar'CO-H]^+$ or $[Ar-H]^+$, 91(12) $[Ar-Me]^+$ or $[PhCH_2]^+$
2,4-$Me_2C_6H_3$ / *o*-HOC_6H_4	251(23) / 250(100)	133(65) / 121(56)	—	249(14) $[M-H]^+$, 238(9) $[M-N_2]^{+\cdot}$, 237(36) $[M-N_2-H]^+$, 209(30) $[M-N_2-CO-H]^+$, 132(54) $[ArCO-H]^{+\cdot}$, 120(24) $[Ar'CO-H]^{+\cdot}$, 92(31) $[Ar-CH_2]^{+\cdot}$, 91(12) $[Ar-Me]^+$ or $[PhCH_2]^+$
2,4-$Me_2C_6H_3$ / *o*-$O_2NC_6H_4$	296(16) / 295(100)	133(46) / 150(24)	105(48) / —	266(10) $[M-N_2-H]^+$, 265(13) $[M-NO]^{+\cdot}$, 132(14) $[ArCO-H]^{+\cdot}$, 104(12) $[Ar-H]^{+\cdot}$, 91(17) $[Ar-Me]^+$ or $[PhCH_2]^+$, 77(32) $[Ph]^+$, 65(19) $[C_5H_5]^+$
2,4-$Me_2C_6H_3$ / *m*-$O_2NC_6H_4$	296(20) / 295(100)	133(85) / 150(7)	105(48) / —	266(40) $[M-N_2-H]^+$, 265(18) $[M-NO]^{+\cdot}$, 132(19) $[ArCO-H]^{+\cdot}$, 104(27) $[Ar-H]^{+\cdot}$, 91(30) $[Ar-Me]^+$ or $[PhCH_2]^+$, 77(32) $[Ph]^+$, 65(30) $[C_5H_5]^+$

(to be continued)

Table 2. (*continued*)

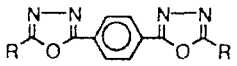
Ar / R	*m/z* (intensity (%))			
	$[M+1]^{+\cdot}$ / $[M]^{+\cdot}$	$[ArCO]^+$ / $[RCO]^+$	$[Ar]^+$ / $[R]^+$	Other ions
2,4-$Me_2C_6H_3$ / *p*-$O_2NC_6H_4$	296(16) / 295(100)	133(86) / 150(63)	105(43) / —	266(19) $[M-N_2-H]^+$, 265(11) $[M-NO]^{+\cdot}$, 132(42) $[ArCO-H]^{+\cdot}$, 104(38) $[Ar-H]^{+\cdot}$, 91(16) $[Ar-Me]^+$ or $[PhCH_2]^+$, 77(32) $[Ph]^+$, 76(14) $[C_6H_4]^{+\cdot}$
2,4-$Me_2C_6H_3$ / 4-C_5H_4N	252(21) / 251(100)	133(92) / 106(25)	105(32) / 78(50)	222(14) $[M-N_2+H]^+$, 208(7) $[M-N_2-Me]^+$, 132(63) $[ArCO-H]^{+\cdot}$, 104(24) $[Ar-H]^{+\cdot}$, 91(13) $[Ar-Me]^+$ or $[PhCH_2]^+$, 65(14) $[C_5H_5]^+$
2,4-$Me_2C_6H_3$ / 3-C_5H_4N	252(23) / 251(100)	133(90) / 106(36)	105(32) / 78(56)	222(11) $[M-N_2+H]^+$, 208(9) $[M-N_2-Me]^+$, 132(26) $[ArCO-H]^{+\cdot}$, 106(36) $[C_6H_4NO]^+$, 104(21) $[Ar-H]^{+\cdot}$, 91(13) $[Ar-Me]^+$ or $[PhCH_2]^+$, 65(12) $[C_5H_5]^+$
2,4-$Me_2C_6H_3$ / 2-Thienyl	257(28) / 256(100)	133(54) / 111(29)	105(11) / 83(39)	227(11) $[M-N_2-H]^+$, 213(7) $[M-N_2-Me]^+$, 199(23) $[M-N_2-CO]^+$, 185(20) $[MH-N_2-CO-CH_3]^{+\cdot}$, 91(7) $[Ar-Me]^+$ or $[PhCH_2]^+$, 51(25) $[C_4H_3]^+$
2,4-$Me_2C_6H_3$ / 4,5-Dibromo-2-furyl	— / 400(49), 398(100), 396(50)	133(82) / 255(11), 253(22) 251(11)	105(29) / —	356(7), 354(14), and 352(7) $[M-N_2-O]^{+\cdot}$, 343(7), 341(14), and 339(7) $[M-N_2-CO-H]^+$, 263(42) and 261(48) $[M-N_2-Br]^+$, 65(18) $[C_5H_5]^+$
2,4,5-$Me_3C_6H_2$ / Ph	265(16) / 264(100)	147(42) / 105(33)	119(14) / 77(18)	235(6) $[M-N_2-H]^+$, 193(19) $[M-N_2-CO-Me]^+$, 146(5) $[ArCO-H]^{+\cdot}$, 118(10) $[Ar-H]^{+\cdot}$, 91(12) $[Ar-Me]^+$ or $[PhCH_2]^+$
2,4,5-$Me_3C_6H_2$ / *o*-HOC_6H_4	281(31) / 280(100)	147(40) / 121(22)	119(7) / —	209(19) $[M-N_2-CO-Me]^+$, 146(5) $[ArCO-H]^{+\cdot}$, 132(21) $[ArCO-Me]^{+\cdot}$, 91(12) $[PhCH_2]^+$, 65(8) $[C_5H_5]^+$
2,4,5-$Me_3C_6H_2$ / *o*-$O_2NC_6H_4$	310(20) / 309(100)	147(90) / —	119(67) / —	279(7) $[M-NO]^{+\cdot}$, 118(38) $[Ar-H]^+$, 91(53) $[PhCH_2]^+$, 77(29) $[Ph]^+$, 76(23) $[C_6H_4]^{+\cdot}$, 75(19) $C_6H_3]^+$
2,4,5-$Me_3C_6H_2$ / *m*-$O_2NC_6H_4$	310(17) / 309(100)	147(79) / —	119(67) / —	280(6) $[M-N_2-H]^+$, 146(26) $[ArCO-H]^{+\cdot}$, 118(14) $[Ar-H]^{+\cdot}$, 104(9) $[PhCNH]^+$, 91(18) $[PhCH_2]^+$, 77(10) $[Ph]^+$, 76(11) $[C_6H_4]^{+\cdot}$, 75(7) $[C_6H_3]^+$
2,4,5-$Me_3C_6H_2$ / *p*-$O_2NC_6H_4$	310(19) / 309(100)	147(87) / —	119(48) / —	146(29) $[ArCO-H]^{+\cdot}$, 91(14) $[PhCH_2]^+$, 77(16) $[Ph]^+$, 75(6) $[C_6H_3]^+$
2,4,5-$Me_3C_6H_2$ / 4-C_5H_4N	266(20) / 265(100)	147(90) / —	119(14) / 78(23)	236(9) $[M-N_2-H]^+$, 146(37) $[ArCO-H]^{+\cdot}$, 118(14) $[Ar-H]^{+\cdot}$, 91(19) $[PhCH_2]^+$, 51(19) $[C_4H_3]^+$, 39(20) $[C_3H_3]^+$
2,4,5-$Me_3C_6H_2$ / 3-C_5H_4N	266(14) / 265(100)	147(47) / —	119(7) / 78(16)	208(14) $[M-N_2-CO-H]^+$, 194(9) $[M-N_2-CO-Me]^+$, 146(11) $[ArCO-H]^{+\cdot}$, 118(7) $[Ar-H]^{+\cdot}$, 91(9) $[PhCH_2]^+$
2,4,5-$Me_3C_6H_2$ / 2-Thienyl	271(24) / 270(100)	147(90) / 111(52)	119(30) / 83(14)	241(25) $[M-N_2-H]^+$, 227(32) $[M-N_2-Me]^+$, 213(16) $[M-N_2-CO]^+$, 199(27) $[MH-N_2-CO-CH_3]^{+\cdot}$, 146(16) $[ArCO-H]^{+\cdot}$, 91(32) $[PhCH_2]^+$
2,4,5-$Me_3C_6H_2$ / 4,5-Dibromo-2-furyl	— / 414(48), 412(100), 410(50)	147(52) / 255(7), 253(15), 251(7)	119(33) / —	370(5), 368(11), and 366(5) $[M-N_2-O]^{+\cdot}$, 357(5), 355(10), and 353(5) $[M-N_2-CO-H]^+$, 277(25) and 275(26) $[M-N_2-Br]^+$, 168(40) $[M-N_2-CO-2\,Br-2\,CH_3]^{+\cdot}$, 146(40) $[ArCO-H]^{+\cdot}$, 91(22) $[PhCH_2]^+$
3-BrC_6H_4 / Ph	— / 302(98), 300(100)	185(35), 183(37) 105(73)	157(25), 155(27) 77(68)	166(20) $[M-N_2-Br]^+$, 165(80) $[M-N_2-HBr]^{+\cdot}$, 76(40) $[C_6H_4]^{+\cdot}$, 75(20) $[C_6H_3]^+$

sented in Table 2, those for 1,4-phenylenebis-1,3,4-oxadiazoles **10** are listed in Table 3.

The most typical ions formed from 2,5-diaryl-1,3,4-oxadiazoles upon electron impact are $M^{+\cdot}$ (as a rule, they produce the most intense peaks), $[ArCO]^+$, $[RCO]^+$, $[Ar]^+$, and $[R]^+$ ions; this agrees with the data of previous publications.[22—24] An important fragmentation route, which was also noted previously,[22] is elimination of N_2 and CO, normally accompanied by abstraction of an H atom. The possible structures of these ions have been discussed previously;[24] they are presented below (**A** and **B**) for the products of fragmentation of diphenyloxadiazole (Scheme 3).

Destruction of the molecular ion with successive elimination of N_2 and H gives ions **C** and **D** (the structures proposed for the products of fragmentation of 2-(2-hydroxyphenyl)-5-phenyl-1,3,4-oxadiazole are shown in Scheme 4).

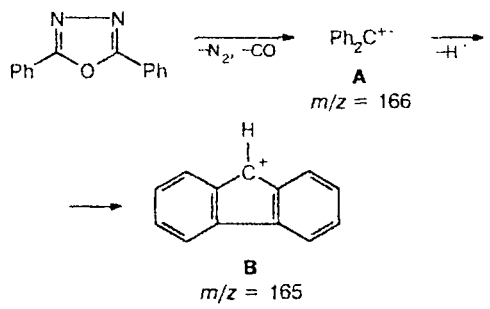
Table 3. Mass spectra of 1,4-phenylenebis-1,3,4-oxadiazoles



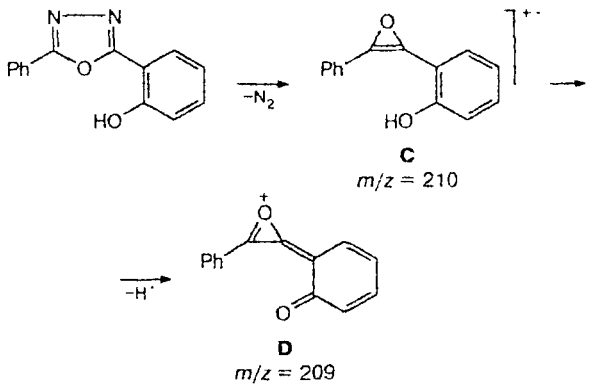
Compound	R	*m/z* (relative intensity (%))								
		$[M+1]^{+\cdot}$ / $[M]^{+\cdot}$	Φ_1 / Φ_2	Φ_3 / Φ_4	Φ_5 / Φ_6	Φ_7 / Φ_8	Φ_9 / Φ_{10}	$[RCN_2]^+$ / $[RCO]^+$	$[RCNH]^+$ / $[RCN]^{+\cdot}$	$[C_7H_7]^+$ / $[R]^+$
10a	Ph	367(28) 366(100)	— 310(8)	250(16) 249(62)	254(6) 247(6)	221(8) 193(49)	165(38) 130(6)	— 105(98)	104(13) 103(18)	91(13) 77(14)
10b	4-C_5H_4N	369(66) 368(100)	340(5) 312(10)	251(47) 250(93)	256(5) 248(7)	222(25) 194(46)	166(25) 130(15)	118(32) 106(79)	105(7) 104(22)	— 78(8)
10c	4-$O_2NC_6H_4$	457(23) 456(100)	426(7) —	295(14) 294(78)	— —	— 238(8)	— —	162(6) 150(9)	149(68) 148(28)	91(17) —
10d	2-HOC_6H_4	399(26) 398(100)	— —	266(4) 265(33)	— 263(13)	237(8) —	181(7) —	— 121(82)	120(4) 119(10)	91(17) —
10e	H	215(11) 214(78)	— —	174(12) 173(100)	102(19) —	145(39) 117(10)	— 130(12)	— —	— —	91(15) —

Note. $\Phi_1 = [M-N_2]^{+\cdot}$, $\Phi_2 = [M-N_2-CO]^{+\cdot}$, $\Phi_3 = [MH-RCN_2]^+$, $\Phi_4 = [M-RCN_2]^+$, $\Phi_5 = [M-2\ N_2-2\ CO]^{+\cdot}$, $\Phi_6 = [M-RCNO]^{+\cdot}$, $\Phi_7 = [M-RCN_2-N_2]^+$ or $[M-RCN_2-CO]^+$, $\Phi_8 = [M-RCN_2-N_2-CO]^+$, $\Phi_9 = [M-RCN_2-N_2-2\ CO]^+$, $\Phi_{10} = [M-RCN_2-RCNO]^{+\cdot}$.

Scheme 3



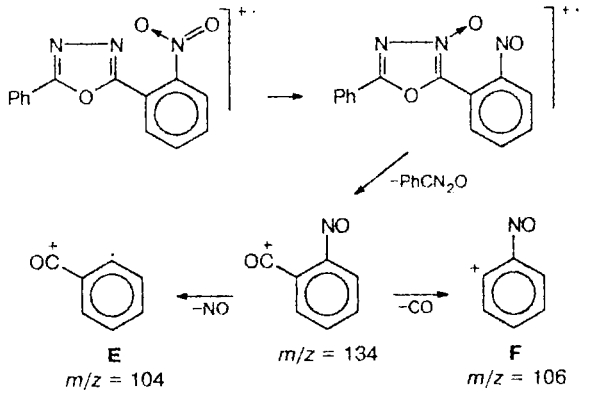
Scheme 4



Some specific features manifest themselves in the mass spectra of nitrophenyl-substituted oxadiazoles. For example, the appearance of ions **B** (m/z = 165) of the composition $[C_{13}H_9]^+$ in the spectra of three isomeric 2-nitrophenyl-5-phenyl-1,3,4-oxadiazoles can be explained by elimination of NO_2 instead of H$^\cdot$ during a rearrangement similar to that shown above for diphenyloxadiazole. In the case of *o*-isomer, successive elimination of $ArCN_2O$ and NO (or CO) fragments to give ions with m/z 104 (**E**) and 106 (**F**) is also typical (Scheme 5).

m/z (relative intensity (%)) Other ions
368(11) $[M+2]^{+\cdot}$, 253(21) $[M-2\,N_2-2\,CO-H]^+$, 238(11), 194(11) $[MH-RCN_2-N_2-CO]^{+\cdot}$, 190(7), 185(11), 183(12), 179(5), 166(8) $[MH-RCN_2-N_2-2\,CO]^{+\cdot}$, 164(16), 148(12), 118(14) $[RCN_2+H]^+$, 106(18) $[RCO+H]^{+\cdot}$, 102(11), 90(31) $[PhCH]^{+\cdot}$, 89(7) $[C_7H_5]^+$, 87(6), 82(6), 76(83) $[C_6H_4]^{+\cdot}$, 75(19), 74(6), 73(9), 69(7), 65(9) $[C_5H_5]^+$, 64(6), 63(17), 62(8), 61(20), 60(11), 57(59), 56(15), 55(24), 53(10), 52(8), 51(29) $[C_4H_3]^+$, 50(22), 46(20)
370(10) $[M+2]^{+\cdot}$, 367(9) $[M-H]^+$, 311(3) $[M-CO-N_2-H]^+$, 295(8), 278(11), 255(5) $[M-2\,N_2-2\,CO-H]^+$, 252(5) $[M+2-RCN_2]^+$, 238(7), 234(13), 223(5) $[MH-RCN_2-N_2]^{+\cdot}$ or $[MH-RCN_2-CO]^{+\cdot}$, 208(8), 195(7) $[MH-RCN_2-N_2-CO]^{+\cdot}$, 193(26) $[M-RCN_2-N_2-CO-H]^+$, 185(6), 183(7), 167(6) $[MH-RCN_2-N_2-2\,CO]^{+\cdot}$, 148(13), 140(8), 139(16), 128(7), 103(5), 102(18), 101(6), 91(14), 90(52) $[C_7H_6]^{+\cdot}$, 88(15), 82(5), 77(77) $[Ph]^+$, 76(30) $[C_6H_4]^{+\cdot}$, 75(18), 74(9), 73(14), 71(6), 69(6), 65(8), 64(10), 63(19), 62(11), 61(16), 60(12), 59(31), 57(49), 56(10), 55(21), 53(14), 52(9), 51(55) $[C_4H_3]^+$, 50(26)
455(7) $[M-H]^{+\cdot}$, 384(13), 339(16), 222(5), 209(6), 177(15), 164(4) $[RCNO]^{+\cdot}$, 163(10) $[RCN_2+H]^{+\cdot}$, 147(6), 130(12) $[M-RCN-RCN_2O]^+$, 121(13) $[RCO-NO+H]^+$, 120(67) $[RCO-NO]^{+\cdot}$, 118(19) $[RCNO-NO_2]^{+\cdot}$, 117(10), 114(8), 104(45) $[RCO-NO_2]^{+\cdot}$, 92(40), 90(30), 79(13) $[PhH+H]^+$, 78(29) $[PhH]^{+\cdot}$, 77(8) $[Ph]^+$
400(4) $[M+2]^{+\cdot}$, 250(9), 238(4) $[MH-RCN_2-N_2]^+$, 180(10), 148(9), 132(5), 130(8), 128(6), 122(8) $[RCHO]^{+\cdot}$, 118(8), 117(6), 113(5), 105(4) $[PhCO]^+$, 104(7) $[PhCNH]^{+\cdot}$, 93(17) $[R]^+$, 92(4) $[C_6H_4O]^+$, 91(12) $[C_7H_7]^+$, 90(9) $[C_7H_6]^{+\cdot}$, 89(6) $[C_7H_5]^+$, 71(9), 69(6), 65(13) $[C_5H_5]^+$, 64(6), 60(7), 59(9), 56(13), 55(20), 51(7) $[C_4H_3]^+$
148(13), 143(6) $[M-RCN_2-NO]^{+\cdot}$, 123(6), 119(7), 118(13) $[MH-RCN_2-N_2-CO]^{+\cdot}$, 116(12) $[M-RCN_2-N_2-CO-H]^{+\cdot}$, 115(10), 114(5), 105(9) $[PhCO]^+$, 104(50) $[PhCNH]^+$, 103(30) $[MH-2\,N_2-2\,CO]^+$, 101(11) $[M-2\,N_2-2\,CO-H]^+$, 99(8), 98(50), 97(7), 96(5), 93(5), 90(54) $[PhCH]^{+\cdot}$, 89(26) $[C_7H_5]^+$, 88(15), 87(9), 83(10), 82(29), 80(6), 77(14) $[C_6H_5]^+$, 76(48) $[C_6H_4]^{+\cdot}$, 75(39), 74(17), 71(5), 70(10), 69(21), 65(9) $[C_5H_5]^+$, 64(14), 63(44), 62(28), 61(8), 60(5), 59(6), 58(57), 57(31), 56(8), 55(32), 54(7), 53(15)

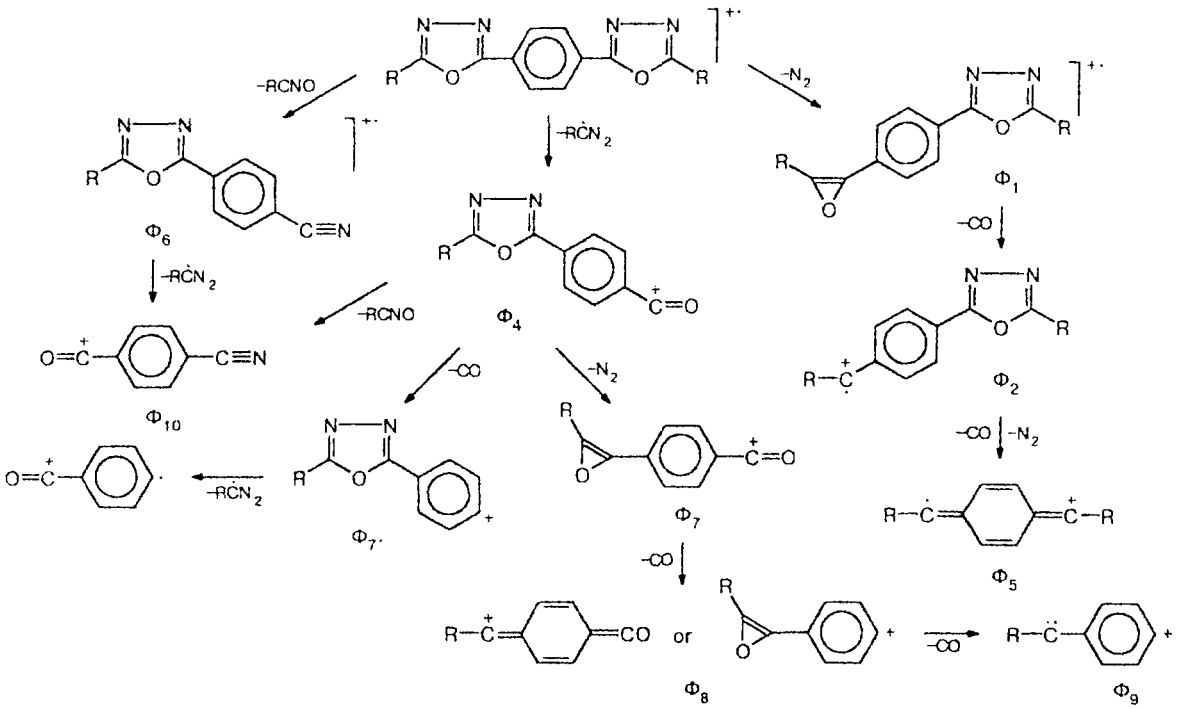
Scheme 5



According to a previous publication,[17] mass spectra of substituted 1,4-phenylenebis-1,3,4-oxadiazoles **10** (R = Ar) contain low-intensity molecular ion peaks, whose fragmentation gives mostly $[M-RCNO]^{+\cdot}$ and $[M-RCN]^{+\cdot}$ ions; the spectra also exhibit peaks for the $RCNO^{+\cdot}$, RCO^+, and $RCN^{+\cdot}$ fragments. The results obtained in the present study did not fully confirm the above data: none of the spectra were found to contain the $[M-RCN]^{+\cdot}$ ion peaks, although the mass spectra of compounds **10a—d** did contain signals for the $[RCN]^{+\cdot}$ and $[RCNH]^+$ fragments. The $[M-RCNO]^{+\cdot}$ ions were found only for compounds **10a,b,d** (R = Ph, 4-C_5H_4N, and *o*-HOC_6H_4); the intensity of the corresponding peaks is low (6 to 13 rel. %).

The most intense peaks in the mass spectra of phenylenebisoxadiazoles **10**, including the previously described[17] spectra of compounds **10a** and **10c**, are molecular ion peaks. The isotope ions, $[M+1]^{+\cdot}$ and $[M+2]^{+\cdot}$, which are generally typical of compounds whose molecules contain more than 10—15 carbon atoms, are also relatively intense. Scheme 6 presented below shows the main fragmentation routes of **10a—e** elucidated in this study and the possible structures of large fragments (Φ_1, Φ_2, Φ_4—Φ_{10}). The most intense peaks for compounds **10** (R = Ar or Het) include as

Scheme 6



well the RCO^+ ion peak, while the R^+ ion accounts for a medium-intensity peak.

The mass spectrum of unsaturated 1,4-phenylenebis-1,3,4-oxadiazole (**10e**) contains some fragments not observed in the spectra of its higher analogs. An example is the low-intensity peak with m/z 143, denoted as $[M-RCNO-N_2]^{+\cdot}$; the structure of this ion is difficult to conceive. Note that the spectrum of compound **10e** contains ions with m/z 105 ($[PhCO]^+$) and 104 ($[PhCNH]^+$). This fact suggests that in the case of compounds **10a,d**, these ions could be formed upon transformations of the central *p*-phenylene moiety of the molecule rather than from the aryl substituents.

Experimental

^1H NMR spectra of compounds **2b,c** and **10e** were measured on a Bruker AC-200 spectrometer (200 MHz) in DMSO-d_6. Mass spectra of compounds **2** were recorded on a Varian MAT CH-6 mass spectrometer; those of compounds **10** were run on a Kratos MS-30 mass spectrometer with direct sample injection into the ion source, an ionizing voltage of 70 eV, an emission current of 0.1 mA, and a temperature in the ionization chamber of 250 °C. Melting points were measured on a Boetius hot-stage apparatus and not corrected.

Commercial samples of benzotrichloride (**1a**), benzohydrazide (**9a**), 2-hydroxybenzohydrazide (**9c**), 4-nitrobenzohydrazide (**9d**), and hydrazine hydrate were used. Formylhydrazine (**9e**) was obtained from ethyl formate and hydrazine by a known procedure[25] and converted into the hydrochloride without additional purification. The latter compound had a melting point of 135—137 °C after washing with acetone. 4-Pyridinecarbohydrazide (**9b**) was synthesized as reported previously.[1] 2-Chlorobenzotrichloride, 4-chlorobenzotrichloride (**1b**), and 1,4-bis(trichloromethyl)benzene (**8**) were prepared by chlorination of 2-chlorotoluene, 4-chlorotoluene, and *p*-xylene, respectively.[26] 2,4,6-Trimethylbenzotrichloride was synthesized by electrophilic trichloromethylation of mesitylene.[27] 3-Bromobenzotrichloride was prepared, as in the previous study,[1] by treatment of 3-bromobenzotrifluoride with $AlCl_3$.

2,5-Diphenyl-1,3,4-oxadiazole (2a). A solution of benzotrichloride (2.7 mL, 19.1 mmol) and $N_2H_4 \cdot H_2O$ (3.82 g, 76.4 mmol) in 10 mL of EtOH was refluxed for 40 min. The precipitated crystals were filtered off, washed with aqueous EtOH, recrystallized from EtOH, and dried in a vacuum desiccator. Yield 2.04 g (96%), m.p. 139.5—141 °C (*cf.* lit.[1,2]).

2,5-Di(4-chlorophenyl)-1,3,4-oxadiazole (2b) was prepared by the same procedure from 4-chlorobenzotrichloride and recrystallized from DMF. Yield 81%, m.p. 243—245 °C (*cf.* lit.[11]), ^1H NMR, δ: 7.23 (s, 8 H, H_{arom}).

2,5-Di(3-bromophenyl)-1,3,4-oxadiazole (2c) was prepared in a similar way from 3-bromobenzotrichloride and recrystallized from DMF. Yield 68%, m.p. 178—180 °C (*cf.* lit.[28]), ^1H NMR, δ: 7.75 (d, 2 H, 6′-H, J = 8 Hz); 7.54 (br.s, 2 H, 2′-H); 7.35 (t, 4 H, 4′- and 5′-H, J = 8 Hz).

1,4-Phenylenebis-1,3,4-oxadiazoles (10a—e). A solution of 1,4-bis(trichloromethyl)benzene (**8**) (1 g, 3.2 mmol) and aroylhydrazine (6.4 mmol) in 10 mL of a mixture of EtOH with Py (5 : 1 v/v) was refluxed for 20—35 h (see Table 1). After cooling, the resulting precipitate was filtered off, washed with EtOH, recrystallized from DMF, and dried in a vacuum desiccator. The characteristics of 5,5′-diphenyl-1,4-phenylenebis-1,3,4-oxadiazole (**10a**), 5,5′-di(4-pyridyl)-1,4-phenylenebis-1,3,4-oxadiazole (**10b**), 5,5′-di(2-hydroxyphenyl)-1,4-phenylenebis-1,3,4-oxadiazole (**10c**), 5,5′-di(4-nitrophenyl)-1,4-phenylenebis-1,3,4-oxadiazole (**10d**), and 1,4-phenylenebis-1,3,4-oxadiazole (**10e**) are listed in Table 1.

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