

ARYL HYDRAZIDATES—I. SYNTHESIS AND THEIR CONVERSION INTO HYDRAZIDES

A NEW CHAPMAN-LIKE REARRANGEMENT IN THE HYDRAZONE SERIES

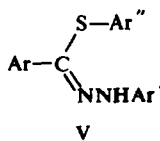
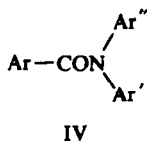
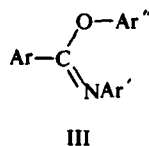
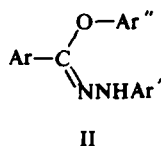
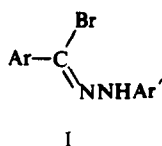
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Abstract— N-arylbenzhydrazidic halides (I) with phenols and thiophenol in ethanol in presence of sodium ethoxide give aryl N-arylbenzhydrazidates (II) and phenyl thiohydrazidates (V), respectively. The esters II resisted hydrolysis but strong acid cleaved them to 2-aroyl-1-arylhydrazines (VII). At high temperatures esters of type II (but not V) undergo quantitative intramolecular rearrangement to give 2-aroyl-1,1-diarylhydrazines (XIV). Structural assignments have been made on the basis of IR and UV spectra and independent synthesis.

THE DIRECT BROMINATION of aldehyde arylhydrazones in AcOH leads to a class of products which have been traditionally described as hydrazidic bromides (I).¹ Such compounds have shown unusual versatility and synthetic utility in 1,3-dipolar cycloadditions² and azocarbonium ion substitution³ reactions giving new products. To date, there is no information regarding the reaction of I with phenols to give aryl hydrazidate esters of type II* other than given in our preliminary communication.⁴ As these esters (II) bear a structural relationship to aryl imidates (III), which rearrange at high temperatures to N-aroilyldiarylamines (IV) (Chapman rearrangement⁵), it would be interesting to investigate the behaviour of II and their thio analogs (V) when similarly heated. Here we report the synthesis and properties of two series of these novel esters. The results are formulated in Schemes 1 and 2.



* By analogy to aryl benzimidates (III), which are named as derivatives of benzimidic acid (PhC(OH):NH), the compounds II of this study are named as esters of the parent benzhydrazidic acid (PhC(OH):NNH_2) and accordingly will be referred to as aryl benzhydrazidates.

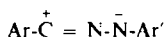
RESULTS AND DISCUSSION

Treatment of PhOH with NaOEt in EtOH followed by the addition of N-*p*-nitrophenylbenzhydrazidic bromide (Ia) at room temp afforded phenyl N-*p*-nitrophenylbenzhydrazidate (IIa) in good yield. Other compounds in series II were similarly prepared (Table 1).

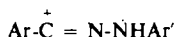
TABLE 1. ARYL N-ARYLBENZHYDRAZIDATES (II, XV)

Compound No.	m.p., °C	Yield, %	Formula	C, %		H, %	
				Calc.	Found	Calc.	Found
IIa	171	65	C ₁₉ H ₁₅ N ₃ O ₃	68.5	68.4	4.5	4.3
IIb	222	60	C ₁₉ H ₁₄ N ₄ O ₃	60.3	60.1	3.7	3.6
IIc	219	60	C ₁₉ H ₁₄ ClN ₂ O ₂	62.2	62.3	3.8	3.7
IId	218	69	C ₂₀ H ₁₇ N ₃ O ₃	69.1	69.1	4.9	4.7
IIe	170	65	C ₂₀ H ₁₇ N ₃ O ₃	69.1	69.0	4.9	4.8
IIf	285	70	C ₁₉ H ₁₄ N ₄ O ₃	60.3	60.2	3.7	3.5
IIg	210	63	C ₁₉ H ₁₃ ClN ₄ O ₃	55.3	55.4	3.2	3.1
IIh	190	72	C ₂₀ H ₁₆ N ₄ O ₃	61.2	61.3	4.1	4.1
IIi	324	65	C ₁₉ H ₁₃ N ₅ O ₇	53.9	53.7	3.1	3.0
IIj	165	60	C ₂₀ H ₁₆ ClN ₃ O ₃	62.9	63.0	4.2	4.1
IIk	325	67	C ₁₉ H ₁₃ ClN ₄ O ₃	55.3	55.5	3.2	3.1
XVI	105	60	C ₂₀ H ₁₈ N ₂ O	79.4	79.5	6.0	5.8
XVm	158	58	C ₁₉ H ₁₆ N ₂ O	79.1	79.0	5.6	5.4
XVn	125	67	C ₁₉ H ₁₅ N ₃ O ₃	68.5	68.3	4.5	4.4

When the reaction of the hydrazidic bromide (Ia) with PhOH was carried out in NaOAc buffered EtOH solution (95%), the expected phenyl ester (IIa) was not isolated; instead N'-benzoyl-N-acetyl-N-*p*-nitrophenylhydrazine (VIa) was obtained, and in the absence of any base catalyst, the reaction yielded β-benzoyl-*p*-nitrophenylhydrazine (VIIa). These results may be rationalized in terms of the suggestion^{3a} that in the presence of strong bases, the reactions of hydrazidic halides (I) proceed *via* a nitrilimine of the type (VIII) and in EtOH and possibly for those buffered with NaOAc *via* the carbonium ion (IX). The latter ion can be attacked by water to form VII and by acetate anion to form the corresponding acetate ester which undergoes OAc → NAc rearrangement to form VI.⁶



VIII



IX

The structural assignments of the hydrazidate esters (II) were based on elemental and spectral analyses. The IR spectra showed, in each case, two characteristic bands at 1264 and 1080 cm⁻¹ (Fig. 1a) assignable to the asymmetric and symmetric stretching vibrations of an aryl ether linkage. The UV spectra of II are similar to those of typical hydrazones;^{6,7} each exhibiting a maximum in the 340–390 nm region (log ε 4–4.5).

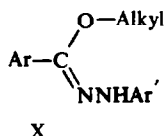
Thiophenol reacts also with I in EtOH in presence of NaOEt to yield the corresponding phenyl N-*p*-nitrophenylbenzthiohydrazidates (V). Both elemental and spectral analyses were in accordance with the assigned structures. The physical constants together with the UV data of this new class of esters are given in Table 2.

TABLE 2. PHENYL N-*p*-NITROPHENYLBENZTHIOHYDRAZIDATES (V)

Compound No.	m.p., °C	Yield, %	Formula	S, %		$\lambda_{\max}^{\text{EtOH}}$ (log e)
				Calc.	Found	
Va	119	80	C ₁₉ H ₁₅ N ₃ O ₂ S*	9.1	9.0	394(4.57), 292(3.85), 232(4.40)
Vb	189	82	C ₁₉ H ₁₄ N ₄ O ₄ S	8.1	8.0	409(4.72), 328(4.08), 238(4.40)
Vc	145	72	C ₁₉ H ₁₄ ClN ₃ O ₂ S	8.3	8.1	394(4.65), 292(3.95), 232(4.45)
Vd	141	82	C ₂₀ H ₁₇ N ₃ O ₂ S	8.8	9.0	400(4.90), 295(4.26), 232(4.49)
Vo	195	80	C ₁₉ H ₁₄ N ₄ O ₄ S	8.1	7.7	394(4.65), 250(4.38)
Vp	114	78	C ₁₉ H ₁₄ ClN ₃ O ₂ S	8.3	8.2	388(4.52), 247(4.12)
Vq	125	80	C ₁₉ H ₁₃ Cl ₂ N ₃ O ₂ S	7.6	7.8	385(4.56), 250(4.20)
Vr	142	70	C ₁₉ H ₁₄ BrN ₃ O ₂ S	7.4	7.4	394(4.58), 298(3.63), 248(4.19)

* Calc.: C, 65.3; H, 4.3; N, 12.0. Found: C, 65.2; H, 4.2; N, 12.1%.

The properties of the aryl hydrazidates (II) were studied and contrasted with those of the recently reported alkyl benzhydrazidates (X).³ Similar to the latter, the aryl hydrazidates (II) were quite stable at room temp; no decomposition being observed after 12 months. When refluxed in either 50% H₂O—dioxan mixture or 30% aqueous EtOH in presence of NH₄OH or KI, ester IIa was recovered unchanged. However, when the latter ester was refluxed in EtOH-concentrated HCl acid mixture (3:1 v/v) it was hydrolyzed to β -benzoyl-*p*-nitrophenylhydrazine (VIIa) in 65% yield. The extent of hydrolysis was found (experimental) to depend on both the acid concentration and duration of reflux. High acid concentration and long reflux time favour hydrolysis of II into VII.



Aryl imidates (III) rearrange on heating to give N-aroxydiarylamines (IV) (Chapman rearrangement).⁵ An attempt to effect the analogous rearrangement of X was unsuccessful.³ However, the aryl benzhydrazidates (II) were found to undergo a Chapman-like rearrangement, when heated at high temperatures. Thus, heating of IIa at 200–220° for 2 h and working up the melt afforded one isolable product which analysed correctly for C₁₉H₁₅N₃O₃. Its IR spectrum revealed a strong CO absorption band at 1650 cm⁻¹ and its UV spectrum in EtOH was different from that of the starting ester (IIa); the band characteristic of the hydrazone chromophore is absent. Initially, this product was assigned⁴ the structure of 1-benzoyl-1-phenyl-2-*p*-nitrophenylhydrazine (XIIa) by analogy to the 1,3-Chapman rearrangement.⁵ This, however, does not prove to be the case, since we have now found that heating of the isomeric ester (XVa) gave the same product as formed on heating IIa. This finding suggests that the structure of the actual product obtained is XIVa and not XIIa.

That the thermal rearrangement of II occurs with formation of hydrazide (XIV) and not (XII) is further confirmed by the identity of the product formed on rearrangement of phenyl *N*-phenylbenzhydrazidate (II_m) and an authentic sample of *N'*-benzoyl-*N,N*-diphenylhydrazine (XIV_m). Both the product and the authentic sample were identical in all respects (m.p., m.m.p., IR and UV).

The rearrangement of II to XIV was also effected by refluxing hydrazidic esters (II) in inert solvents. Thus, both (XIV_m) and XIV_a were obtained in quantitative yields when the corresponding esters II_m and II_a, respectively, were refluxed in xylene for 4 h. The latter conditions proved to be more convenient to effect the rearrangement of the esters (II) (experimental).

By use of either technique outlined above, it was possible to prepare a series of eight *N'*-aroyl-*N,N*-diarylhydrazines (XIV). The properties of these compounds are given in Table 3. The IR spectra shown in Fig. 1 illustrate the general features of the whole series of the hydrazides (XIV) as compared with those of the corresponding esters (II).

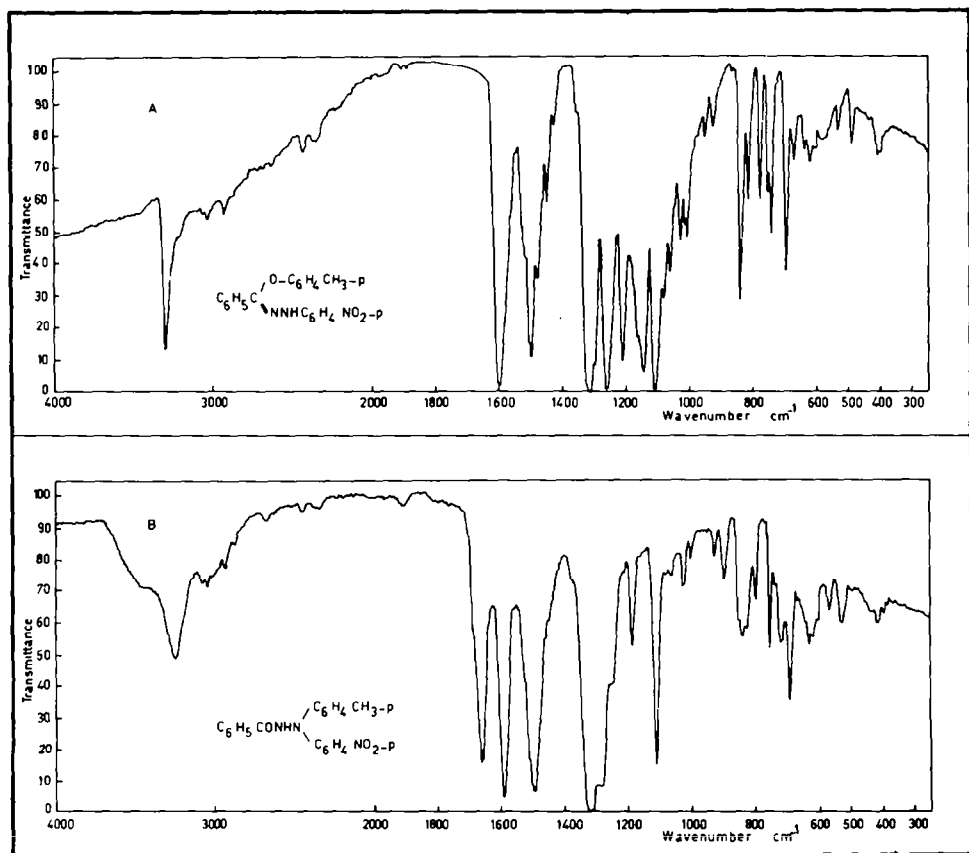


FIG 1. Infrared absorption spectra of *p*-Tolyl *N*-*p*-nitrophenylbenzhydrazidate (A) and its rearrangement product (B) in KBr

TABLE 3. N'-AROYL-N,N-DIARYLHYDRAZINES (XIV)

Compound No.	m.p., °C	Method	Yield, %	Formula	C, %		H, %	
					Calc.	Found	Calc.	Found
XIVa	180	A	45	$C_{19}H_{15}N_3O_3$	68.5	68.3	4.5	4.3
		B	85					
XIVb	226	A	52	$C_{19}H_{14}N_4O_5$	60.3	60.1	3.7	3.6
XIVc	198	B	75	$C_{19}H_{14}ClN_3O_3$	62.1	62.0	3.8	3.5
XIVd	176	A	42	$C_{20}H_{17}N_3O_3$	69.1	69.2	4.9	4.7
		B	80					
XIVe	188	B	77	$C_{20}H_{17}N_3O_3$	69.1	69.1	4.9	4.8
XIVj	226	B	79	$C_{20}H_{16}ClN_3O_3$	62.9	62.7	4.2	4.1
XIVh	210	A	60	$C_{20}H_{16}N_4O_5$	61.2	61.1	4.1	4.0
XIVm	190	B	80	$C_{19}H_{16}N_2O$	79.1	79.0	5.6	5.4

A crossover experiment indicates that the hydrazidate-hydrazide rearrangement is intramolecular. For example, a mixture of the isomeric esters IIa and XVa gave the hydrazide XIVa in almost quantitative yield. The nonformation of either N'-benzoyl-N,N-diphenylhydrazine or N'-benzoyl-N,N-di-(*p*-nitrophenyl)hydrazine is clearly compatible with an intramolecular mechanism.

The foregoing results indicate that the thermal rearrangement of II to XIV involves a 1,4-shift of an aryl group from oxygen to nitrogen. The reaction seems to proceed *via* a five-membered transition state (XIII) and may be considered as a nucleophilic attack by the anilinic nitrogen atom on the migrating group. The formation of XIV and not XII on rearrangement of II might be attributed to the higher stability of the five- (XIII) than the four- (XI) membered cyclic transition states required for the formation of XIV and XII, respectively.

Attempts to effect the analogous rearrangement of the thiohydrazidate esters (V) were unsuccessful; in each case the ester was recovered unchanged.

EXPERIMENTAL

M.ps. are uncorrected. The IR spectra were recorded on a Beckman IR4 spectrophotometer either in nujol or as KBr discs. The UV spectra were recorded in EtOH on a Beckman DK spectrophotometer.

The hydrazidic bromides (I) used in the synthesis of II and V were prepared by bromination of the corresponding benzaldehyde *p*-nitrophenylhydrazones in AcOH as described;¹ the physical data obtained for compounds prepared agreed with literature values.¹

N-Phenylbenzhydrazidic chloride was prepared as previously described by the action of PCl_5 on β -benzoylphenylhydrazine in ether,⁸ m.p. 130° (lit.⁸ m.p. 130.5°). N'-benzoyl-N,N-diphenylhydrazine (XIVm) was prepared by benzoylation of asymmetric diphenylhydrazine, m.p. 190° (lit.⁹ m.p. 190°).

Reaction of I with phenols.—(a) *In presence of EtONa.* To 25 ml of absolute EtOH was added 0.11 g (0.005 g atom) of Na. After conversion to EtONa, the solution was cooled to room temp and PhOH or its derivative (0.005 mole) added. To the resulting soln, a suspension of hydrazidic halide (0.005 mole) in 10 ml of EtOH was added. The mixture soon turned deep violet. It was stirred for 15 min and left overnight at room temp. The crude ester that precipitated was collected and recrystallized from AcOH. The compounds prepared and their physical constants are shown in Table 1.

Reaction of thiophenol with I, when carried out in the same way, afforded the phenyl thiohydrazidate esters (V) listed in Table 2.

(b) *In presence of AcONa.* A solution of AcONa (0.41 g) in H_2O (2 ml) was added to a suspension of Ia (1.6 g) in EtOH (25 ml) containing PhOH (0.47 g) and the mixture refluxed for 1 h, cooled, diluted with

water and the solid precipitated was collected. Recrystallization from AcOH gave N-acetyl-N'-benzoyl-N-p-nitrophenylhydrazine (71 %), pale yellow needles, m.p. 172–173°. Its IR spectrum showed two C=O bands at 1730 and 1670 cm^{-1} . (Calc. for $\text{C}_{15}\text{H}_{13}\text{N}_3\text{O}_4$: C, 60.19; H, 4.38. Found: C, 60.3; H, 4.4 %.)

(c) *In absence of base catalysts.* Equivalent amounts of PhOH and Ia were refluxed in EtOH (95 %) for 4 h and the mixture cooled. The pale yellow crystalline solid precipitated was collected (m.p. 186°). Recrystallization from dil. AcOH gave colourless needles (60 %) of N'-benzoyl-N-p-nitrophenylhydrazine, m.p. 191° (identified by comparison with authentic sample).

Attempts at Hydrolysis of II. A suspension of IIa (0.2 g) in EtOH (95 %) (40 ml) was refluxed for 72 h and cooled. The solid precipitate was collected and after recrystallization (EtOH), proved to be identical in all respects (m.p., IR and UV) with starting ester.

When this experiment was repeated in presence of either KI (0.6 g); AcONa (0.6 g) or NH_4OH (25 %, 2 ml), the starting ester was recovered in ca. 89 % yield. The same result was observed when this same ester was refluxed in 1:1 dioxan–water mixture for 4 h.

In another attempt, IIa (0.3 g) was refluxed in EtOH (30 ml) and 12 M conc HCl (10 ml), for 4 h, then cooled. Addition of water to the mixture precipitated N'-benzoyl-N-p-nitrophenylhydrazine (VIIa) (65 %), m.p. 191° after being recrystallized from AcOH (identified by m.m.p. with authentic sample).

When the latter experiment was repeated using 30 ml EtOH and 2 ml 2 M HCl, and worked up as above, starting ester was recovered in 78 % yield.

Thermal rearrangement of hydrazidates. Method-A. Phenyl N-p-nitrophenylbenzhydrazidate (IIa) (0.5 g) was placed in a test tube and heated in an oil bath at 200–220° for 2 h. The dark melt was cooled and acetone extracted. Solvent was evaporated and the residue boiled with benzene (20 ml), cooled and filtered. Recrystallization of the crude solid from AcOH gave 0.3 g (45 %) of pale yellow solid, m.p. 179–180°. (Calc. for $\text{C}_{15}\text{H}_{13}\text{N}_3\text{O}_3$: C, 68.46; H, 4.35. Found: C, 68.6; H, 4.4 %). IR (KBr) showed bands at 3250 (NH) and 1650 (C=O) cm^{-1} .

Similar treatment of p-nitrophenyl N-phenylbenzhydrazidate (XVa) gave a product proved to be identical in all respects (m.p., IR and UV) with that obtained above by pyrolysis of IIa.

Method-B. Phenyl N-phenylbenzhydrazidate (IIm) (0.5 g) in xylene (15 ml) was refluxed for 4 h. The white solid precipitated on cooling was collected (0.45 g). Recrystallization from AcOH gave 0.4 g (80 %) of N'-benzoyl-N,N-diphenylhydrazine (XIVm), m.p. 190°, identified by m.m.p. and the identity of its IR spectrum with an authentic sample.

Characteristics of other rearrangement products (XIV) prepared as above are listed in Table 3.

Rearrangement of a mixture of the isomeric esters IIa and XVa. A suspension of a mixture of IIa and XVa (0.25 g each) in 20 ml xylene was refluxed for 4 h. On cooling a pale yellow solid precipitated and was collected and dried. Recrystallization (AcOH) gave 0.4 g (80 %) of N'-benzoyl-N-phenyl-N-p-nitrophenylhydrazine (XIVa), m.p. 180°, not depressed when mixed with the product formed on pyrolysis of either IIa or XVa.

Attempted thermal rearrangement of thiohydrazidates (V). A suspension of Va (0.5 g) in xylene (15 ml) was refluxed for 4 h and cooled. The yellow solid precipitated was collected. Recrystallization from AcOH gave 0.41 g (82 %) of yellow crystalline solid, m.p. 195°, not depressed when mixed with the starting ester (Va). The ester Vb was recovered unchanged when similarly treated.

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