

BIPHENYL SERIES—II*

THE KINETICS OF PIPERIDINO-DEBROMINATION REACTIONS OF 3'-, 4'-SUBSTITUTED 3-NITRO-4-BROMOBIPHENYLS

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Abstract—In order to obtain information on the electronic transmission of polar substituent effects in biaryl systems, a kinetic study of the piperidino-debromination reactions of some 3'-, 4'-substituted 3-nitro-4-bromobiphenyls (substituents = H, Hal, CH₃CO, SO₂CH₃, NO₂) in methanol has been carried out.

A good fit to the Hammett equation was found with $\rho = +1.00$.

The experimental data obtained show that the polar effects of 3'-substituents and 4'-Hal in the reactions studied are similar to the ones exerted by the same substituents in the 5- and 4-positions respectively in the piperidino-debromination reaction of *o*-nitrobromobenzene.

For the strongly electronwithdrawing 4'-substituents (COCH₃, SO₂CH₃, NO₂) we found it necessary to use values [$\sigma_p + 0.32(\sigma^- - \sigma_p)$] for the substituent constants. This result is consistent with a lower contribution of extraconjugative effects to the total polar effect for the 4'-substituents with respect to that reported for the *para*-substituents in nucleophilic substitution reactions on benzenic derivatives.

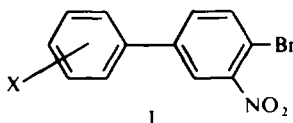
THE effect of substituents in *meta*, *para* and *ortho* positions with respect to the leaving group in nucleophilic substitutions has been extensively studied on several aromatic systems,¹ but almost completely neglected for the biaryl systems. The only information reported² concerning the effect of substituents in nucleophilic substitution reactions on biphenyls, shows that in passing from 3-nitro-4-bromobiphenyl to 3,4'-dinitro-4-bromobiphenyl the introduction of a nitro group in the 4'-position increases the rate of piperidino-debromination in dioxan by a factor of about 12. It is known moreover that 4-bromo-4'-nitrobiphenyl does not undergo piperidino-debromination.

The effect of substituents in the biphenyl system has been studied more closely (especially for the 4'-substituents) in reactions different from the nucleophilic type.³⁻⁷ In some cases⁵⁻⁷ the data obtained have been correlated by means of the sigma-rho Hammett relationship. Generally for such reactions a similar transmission of the effects of substituents between the 4- and 4'-positions of biphenyl and the *para*-benzene positions has been observed. But this is not the case in the transmission of the substituent effects between the 3'- and 4-biphenyl positions and the *meta*-benzene positions.⁸

Dewar and Grisdale⁹ have calculated some constants $\sigma_{4,4'}$ and $\sigma_{4,3'}$ which should indicate the effects of substituents in the 4'- and 3'-positions respectively of biphenyl on appropriate reactions at the 4-position or on a side-chain attached to that position. Such constants in some cases gave poor correlations.^{7, 8}

* Part I: C. Dell'Erba, G. Garbarino and G. Guanti, *Tetrahedron* 27, 113 (1971)

In addition to our previous reports concerning transmission of substituent effects in homocyclic and heterocyclic biaryls¹⁰ we have carried out kinetic investigations on the piperidino-debromination reaction of some 3', 4'-substituted 3-nitro-4-bromobiphenyls (I).



X = H, 3'- and 4'-Hal (Hal = Cl, Br, I), 3'- and 4'-SO₂CH₃, 3'- and 4'-NO₂, 4'-COCH₃.

This work was done in order to compare the effects of substituents in 3'- and 4'-positions with those already known exerted by the same substituents in the 5- and 4-positions respectively in analogous reactions on *o*-nitrohalobenzenes, and hence to clarify the nature of the possible interactions between the substituents and the carbon 4, reaction centre, in the biphenyl derivatives used.

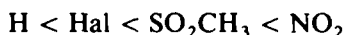
For comparison the rate of piperidino-debromination of *o*-nitrobenzene in the same experimental conditions has been measured.

RESULTS AND DISCUSSION

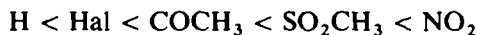
As can be seen from data in Table 2, passing from *o*-nitrobenzene to 3-nitro-4-bromobiphenyl, the introduction of a phenyl group in the *para*-position with respect to the reaction centre increases the rate of piperidino-debromination at 39.86° by a factor ($k_{4-C_6H_5}/k_{4-H}$) = 2.26.

This result agrees with the effects which the *para*-phenyl substituent exerts in the reaction considered. Moreover, the data listed in Table 2 show that the introduction of electron-withdrawing groups, both in 3'- and 4'-positions, causes an increase in the reaction rate.

The reaction rates change with the substituent in the order:



for the 3'-substituted derivatives and

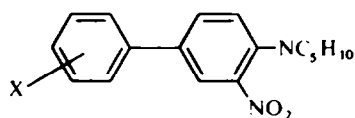


for the 4'-substituted ones. Moreover, the effects exerted by the same substituents in 3'- and 4'-biphenyl positions are, in the studied reactions, comparable to the ones exerted by the same substituents in analogous reactions in *meta*- and *para*-benzene positions respectively.

Therefore we thought it possible to correlate the kinetic data obtained by means of the $\rho\sigma$ Hammett relationship. By plotting $\log k_{3'\text{-subst}}$ and $\log k_{4\text{-Hal}}$ at 39.86° against the σ_{meta} and σ_{para} values respectively, a straight line was obtained with $\rho = +1.00$ ($r = 0.997$).

For the experimental data concerning the strongly electronwithdrawing groups in 4'-position (COCH₃, SO₂CH₃ and NO₂), in contrast to the benzene series,^{1, 11} intermediate values between σ_{para} and σ^- would appear necessary.

TABLE I



X =	Crystallization solvent	m.p.	Found %		Required %		λ_{\max}^a (m μ)	log ϵ^a
			N	Hal	N	Hal		
H	ligroin	102°	9.97	—	9.93	—	420	3.10
3'-Cl	ligroin	76°	9.02	11.54	8.85	11.19	420	3.16
3'-Br	ligroin	74°	7.83	22.16	7.76	22.12	418	3.15
3'-I	ligroin	70°	7.05	—	6.86	—	418	3.15
3'-NO ₂	methanol	86°	13.05	—	12.84	—	406	3.18
3'-SO ₂ CH ₃ ^b	ligroin	116°	7.86	—	7.78	—	420	3.16
4'-Cl	ligroin	99°	9.08	11.52	8.85	11.19	408	3.16
4'-Br ^c	ligroin	85°	—	—	—	—	420	3.14
4'-I	ligroin	104°	7.03	—	6.86	—	418	3.14
4'-SO ₂ CH ₃ ^d	ligroin	136°	7.92	—	7.78	—	414	3.20
4'-COCH ₃	ligroin	86°	8.78	—	8.64	—	414	3.21
4'-NO ₂	methanol	102°	13.05	—	12.84	—	354	4.18

^a In methanol.

^b Found: S. 8.87. Required: S. 8.89%.

^c R. S. W. Le Fèvre and E. E. Turner. *J. Chem. Soc.* 2041 1926.

^d Found: S. 8.95. Required: S. 8.89%.

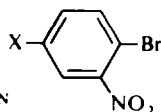


TABLE 2. KINETIC DATA FOR THE REACTIONS BETWEEN AND PIPERIDINE IN METHANOL

X =	$10^6 k, 1 \text{ mol}^{-1} \text{ sec}^{-1}$ at various temperatures (°C) ^a			$\Delta H^{\ddagger b}$ (kcal/mole)	$-\Delta S^{\ddagger c}$ (e.u.)
	39.86°	49.92°	60.00°		
H	0.78	—	—	—	—
C ₆ H ₅	1.78	4.50	9.31	16.6	31.8
3-Cl-C ₆ H ₄	3.86	9.27	19.62	16.2	31.7
3-Br-C ₆ H ₄	4.23	10.15	21.32	16.1	31.7
3-I-C ₆ H ₄	4.20	10.73	21.15	16.1	31.7
3-CH ₃ SO ₂ -C ₆ H ₄	7.16	16.95	36.08	16.1	30.8
3-O ₂ N-C ₆ H ₄	8.89	19.95	43.56	15.8	31.3
4-Cl-C ₆ H ₄	2.69	6.63	14.45	16.8	30.5
4-Br-C ₆ H ₄	3.16	8.06	16.81	16.7	30.5
4-I-C ₆ H ₄	3.28	8.06	16.93	16.4	31.5
4-CH ₃ -CO-C ₆ H ₄	6.64	15.69	31.41	15.5	32.8
4-CH ₃ SO ₂ -C ₆ H ₄	11.06	26.30	51.74	15.4	32.2
4-O ₂ N-C ₆ H ₄	15.79	34.69	69.57	14.7	33.6

^a The rate constants are accurate to better than $\pm 2\%$.

^b At 40°. The probable error is ± 0.3 kcal/mole.

^c At 40°.

To the kinetic data obtained with these three last substituents we have therefore applied the modified Hammett relation¹²

$$\log k_X/k_H = \rho [\sigma_p + R(\sigma^- - \sigma_p)]$$

By using as ρ -value the one ($\rho = 1$) calculated from the kinetic constants of all the other substituents, we obtained a good correlation (Fig 1) also with the experimental data from acetyl-, methylsulphonyl and nitro groups in 4'-position with $R = 0.32$ ($r = 0.997$).

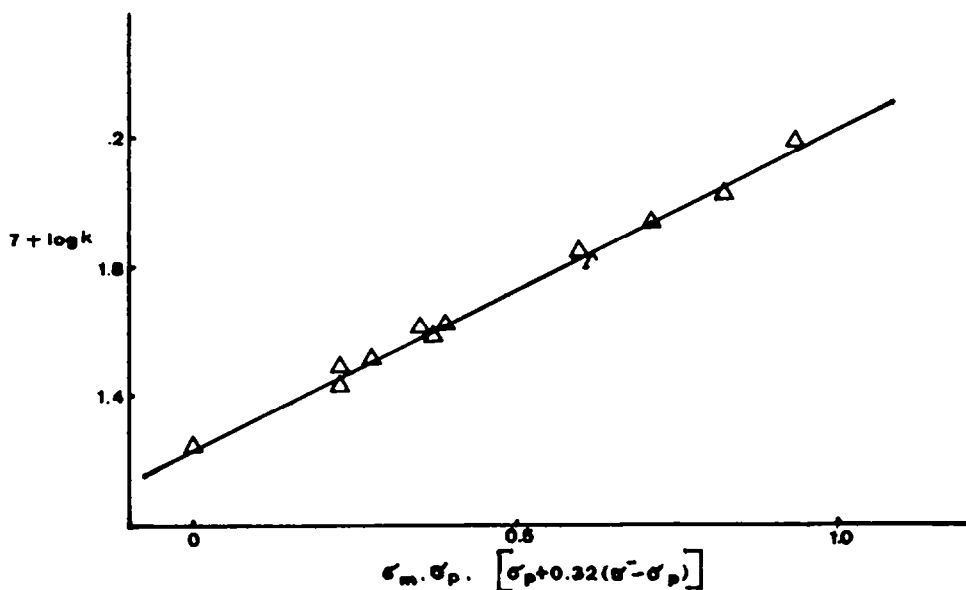


FIG 1.

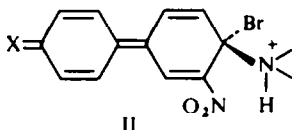
The experimental data obtained therefore indicate that, also in nucleophilic substitution, the biphenyl and benzene systems show many more analogies in the transmission of the substituent effects than those suggested by Dewar and Grisdale.⁹

Moreover, the correlation of the kinetic data with the benzene σ -values is proof of the independence of the dihedral angle between the two rings from the nature of 3'- and 4'-substituents.

The ρ -value obtained ($\rho = 1$) is much lower than those reported ($\rho = 3 \div 5$) for analogous reactions on *meta*- and *para*-substituted benzene derivatives.^{1, 11} The low ρ -value can be related to the greater distance between the reaction centre and the substituents and to the reduced interactions between 4- and 3'- or 4'-positions depending on the non-coplanarity of the benzene rings.

Admitting that the 3'-substituents exert mainly inductive effects on the carbon 4, comparable with those exerted by the same substituents in the *meta*-position in benzene substrates, the data obtained for the 4'-substituents show that, in the reactions studied, the extra-conjugative interactions between strongly electronwithdrawing substituents and the reaction centre must be considered low.

This result suggests a lower contribution of structure like II to intermediate



complex with respect to what happens in the same reactions on *para*-substituted benzene derivatives.

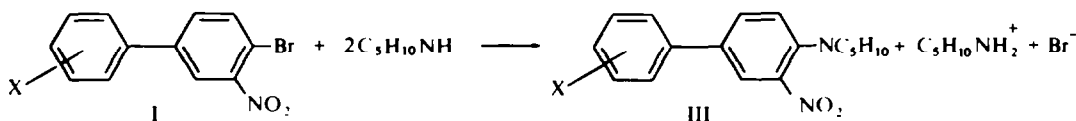
This result, which may explain the lack of reactivity of 4-bromo-4'-nitrobiphenyl towards nucleophilic reagents, can be related both to the non-coplanarity of biphenyl systems and to a probable poor tendency of these systems to employ, in the conjugative effects, the π -electrons of both the benzene rings.

Our next report will try to clarify such effects.

EXPERIMENTAL

Substituted 3-nitro-4-bromobiphenyls were prepared by the techniques described.¹³ Commercial *o*-nitrobromobenzene was purified by crystallization from aqueous MeOH. Piperidine was purified by drying over KOH and distillation. MeOH was dried and distilled as described.¹⁴

The reactions are represented by Eq 1.



The compounds III are coloured and the progress of the reactions was conveniently followed photometrically with the kinetic technique reported.¹⁵

The substituted N-4-xenyl-piperidines (III) were prepared by refluxing the corresponding substituted 3-nitro-4-bromobiphenyls (0.002 molé) with piperidine (0.004 mole) in MeOH (10 ml) for 2 hr. After cooling, the mixture was evaporated at reduced pressure. The residue was washed with water and crystallized (Table 1).

The N-2-nitrophenyl-piperidine (m.p. 81°)¹⁶ gives in MeOH $\log \epsilon = 3.09$ ($\lambda = 408 \text{ m}\mu$).

All rate determinations were performed with piperidine in large excess over the biphenyl substrates. The initial concentrations were *ca* $25 \cdot 10^{-4} \text{ M}$ for the substrate* and $9.2 \cdot 10^{-2} \text{ M}$ for the piperidine. Quantitative yields for the expected products (III) were indicated by photometric data. Good pseudo first-order kinetic plots were obtained in all cases. The pseudo first-order rate coefficients were divided by the initial piperidine concentration to convert them into second-order rate coefficients. In Table 2 are reported the second-order rate coefficients obtained at various temps and the activation parameters calculated.

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* Only for the 4-bromo-3,3'-dinitrobiphenyl the concentration used was $15 \cdot 10^{-4} \text{ M}$ owing to the lower solubility of this compound in MeOH.

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