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# THE MECHANISM OF THE REARRANGEMENT OF p-QUINAMINES TO 4-AMINODIPHENYLETHERS

## AN ANALOGUE OF THE BENZIDINE REARRANGEMENT

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SOME thirty years ago,[1] Fries *et al.* reported that 4-bromocyclohexadienones react with aromatic amines to give products to which, on the basis of the method of preparation, they assigned 4-arylaminocyclohexadienone structures (such as I), and which they named "quinamines" by analogy with the known "quinols". In acidic solutions, quinamines rearranged to form completely aromatic products in very high yields. Quinamines with unsubstituted *para* positions in the aniline ring gave principally 4-aminodiphenylethers (i.e. IIa from Ia),[1a] while in quinamines obtained from *para* substituted anilines, substituents on the cyclohexadienone ring were displaced and mixtures of diphenyls (III from Ic) and diphenylamines (IV from Ic) were obtained.[1b] The only suggestion offered as to the mechanisms of these fascinating rearrangements was that reversion to a 4-halocyclohexadienone and an aniline might be a first step.[1b]

We were attracted to a study of these reactions by the close apparent relationship between the "quinamine" and benzidine rearrangements: the

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[1] *a* K. Fries and G. Oehmke, *Liebigs Ann.* *462*, 1 (1928);
*b* K. Fries, R. Boeker and F. Wallbaum, *Ibid.* *509*, 73 (1934).

proposed structures (I) are similar in geometry to hydrazobenzenes,[2] similar reaction paths can be written for the two types of rearrangements (<u>vide infra</u>) and the products of the two reactions show a marked resemblance.[3]

It is the purpose of this communication to demonstrate that the rearrangement of quinamines to diphenylethers, like the benzidine rearrangement,[4] is completely intramolecular, and to offer kinetic evidence relating to the nature of the transition state in the rearrangement.

Our spectroscopic data have confirmed Fries' structural assignments. The presence of strong carbonyl peaks at 5.95-6.0μ in the infrared spectra (Nujol mull) of all quinamines eliminates O,N-diaryl hydroxylamines as possible structures, while the ultraviolet spectra ($\lambda_{max}$ 247 to 258 mμ, depending upon the substituents on the cyclohexadienone ring) are consistent with structure I but not with a 2-arylaminocyclohexadienone structure (V).[5]

We obtained a quantitative yield of amine hydrochlorides when an equimolar mixture of Ia and Ib in methanol solution was reacted with aqueous hydrochloric acid and the solvent evaporated. The crude product was dissolved in an equivalent amount of sodium methoxide in methanol, and the methanolic solution analyzed by gas-liquid chromatography on a 10 ft silicone grease column at 250°. No trace of IIc or IId could be found in the mixture of IIa and IIb. Analysis of synthetic mixtures of IIa-d showed that 0.5 mole percent of IIc or IId could readily be detected under identical conditions. Since Ia was found to rearrange only 1.7 times as fast as Ib under

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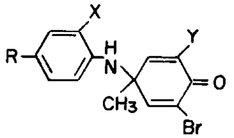
[2] The angle between the two rings of I in the "eclipsed" conformation is 40°; of hydrazobenzene, 40°. The distance between the carbonyl oxygen and the aniline ring in I is 4.31 A°; between the two <u>para</u> positions in hydrazobenzene, 4.31 A°.

[3] II can be considered as analogous to benzidines, III to diphenylines, and IV to <u>ortho</u>-semidines.

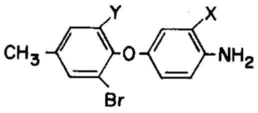
[4] <u>a</u> C.K. Ingold and H.V. Kidd, <u>J. Chem. Soc.</u> 984 (1933); <u>b</u> D.H. Smith, J.R. Schwartz and G.W. Wheland, <u>J. Amer. Chem. Soc.</u> <u>74</u>, 2282 (1952).

[5] <u>a</u> L. Denivelle and R. Fort, <u>C.R. Acad. Sci., Paris</u> <u>238</u>, 1132 (1954); <u>b</u> F. Wessely and F. Sinwell, <u>Monat. Chem.</u> <u>81</u>, 1055 (1950).

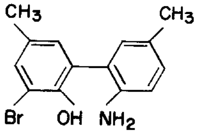
the conditions employed, the lack of "cross-over products" shows that the quinamine rearrangement is completely intramolecular.



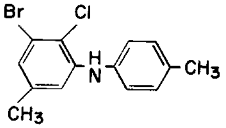
I a, $X = CH_3$ , $Y = Br$ , $R = H$
b, $X = C_2H_5$ , $Y = CH_3$ , $R = H$
c, $X = H$ , $Y = Br$ , $R = CH_3$



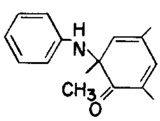
II a, $X = CH_3$ , $Y = Br$
b, $X = C_2H_5$ , $Y = CH_3$
c, $X = CH_3$ , $Y = CH_3$
d, $X = C_2H_5$ , $Y = Br$



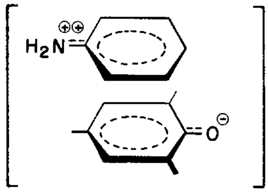
III



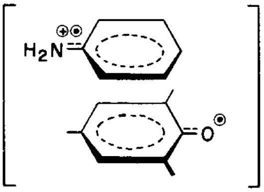
IV



V



A



B

The kinetics of the rearrangement of quinamines with unsubstituted para positions in the aniline ring were studied in a mixture of nine parts (by volume) of methanol to one of water at 26.0°. The disappearance of the cyclohexadienone absorptions at 247-258 mμ was followed spectroscopically. The reactions were first order in hydrogen ion and in quinamine, and were found to be exceptionally rapid ($k_2$ for Ia was 24.8 l/mole/sec). Electron donating substituents on the aniline ring markedly increased the rate of reaction, but similar substituents on the cyclohexadienone ring slightly decreased the rate. (Relative rearrangement rates for quinamines with methyl, bromine, and chlorine alpha to the carbonyl group were ca. 1:2:3).

The asymmetry of the quinamine molecule (as compared to that of hydrazobenzene), as well as the presence of only one proton in the transition state, should simplify the task of mechanistic interpretation.

The rearrangement of quinamines to diphenyl ethers, as well as the benzidine rearrangement, seems (in the light of present knowledge) to be best represented in terms of a transition state involving a "pi complex" of two roughly parallel aromatic rings.[6] Since the inhibiting effects of electron donating substituents on the cyclohexadienone ring are inconsistent with a representation of this complex involving a positively charged phenol ring, transition states A and B are left under consideration. The comparatively small effect of substituting a halogen for a methyl group on the cyclohexadienone ring argues against the formation of a phenoxide ion in the transition state,[7] and therefore against a transition state resembling A. The electron distribution in the transition state can, therefore, probably be best represented as resembling the radical complex B.[8]

The small rate enhancing effects of electron withdrawing substituents on the cyclohexadienone ring may be attributed to weakening of the C-N bond by electrostatic repulsion of the anilinium ion in the ground state. These substituents, in this view, serve a function similar to that of the second hydrogen ion in the benzidine rearrangement.[9]

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[6] M.J.S. Dewar, The Electronic Theory of Organic Chemistry pp. 235-240. Oxford University Press, London (1948).

[7] In contrast, substitution of a chlorine or bromine atom for the methyl group in o-cresol increases the acidity by a factor of 60. J.M. Vandenbelt, C. Henrich and S.G. Vanden Berg, Analyt. Chem. 26, 726 (1954).

[8] A similar transition state has recently been proposed for the rearrangements of N-nitroanilines to nitroanilines; W.N. White et al., J. Amer. Chem. Soc. 83, 2025 (1961).

[9] a G.S. Hammond and H.J. Shine, J. Amer. Chem. Soc. 72, 220 (1950);
b R.B. Carlin, R.G. Nelb and R.C. Odioso, Ibid. 73, 1002 (1951).