moment of transition state has sometimes been used as a theoretical parameter, but it need not be independent of changing solvent even if the basic mechanism is unaffected by such change. As a minimum, it appears that the separation of charge (dipole moment) and the polarizability of the transition state will both have to be considered before it is possible to explain effects of several aprotic solvents on the rates of several polar reactions. More data will be needed to define the range of the problem.

Effects of Substituents. The rates are reduced by chlorine substitution in one of the aromatic rings, the effect being much larger for *meta* than for *para* substitution. The direction of the rate change is that anticipated for the charge distribution proposed for the transition state, and the magnitude is perhaps somewhat less than that from substitution in benzoyl iodide.[3] Somewhat surprisingly, the effect of chlorine substitution appears to be greater in carbon tetrachloride than in hexane.

The rates in hexane can be roughly correlated with σ^+ values[5] to give a ρ of about -4, but more compounds must be studied before a really quantitative discussion of substituent effects is possible. Unfortunately, strongly electron-withdrawing substituents such as *p*-nitro and *p*-cyano apparently render benzhydryl iodide so unstable to radical decomposition that the desired compounds cannot be synthesized and studied.[6]

In spite of these synthetic complications, it is obvious that the benzoyl and benzhydryl iodides exchange with iodine by very polar mechanisms even in solvents of low dielectric constant. These reactions appear to offer exceptionally good opportunities to study substituent and solvent effects on transition states more polar than can usually be formed in such solvents.

Acknowledgment. This work was supported in part by a Contract of the United States Atomic Energy Commission and by a N.A.T.O. Science Fellowship awarded to Dr. Muizebelt by the Netherlands Organization for the Advancement of Pure Research (Z. W. O.).

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(5) H. C. Brown and Y. Okamoto, *J. Amer. Chem. Soc.*, **80**, 4979 (1958).

(6) Observations of Dr. J. A. Hemmingson.

Formation of an Intermediate in Nucleophilic Substitution at Dicoordinated Sulfur

Ennio Ciuffarin and Franco Griselli

Contribution from the Istituto di Chimica Generale, Università di Pisa, 56100 Pisa, Italy. *Received July 29, 1969*

Abstract: The rate of reaction between *p*-nitrobenzenesulfenyl choride and aniline has been measured in benzene at 20° with a stopped-flow spectrophotometer. In the absence of additives the pseudo-second-order rate coefficient, k_2, tends to a limiting value with increasing aniline concentration. In the presence of tetra-*n*-butylammonium perchlorate, k_2 either is independent of the concentration of nucleophile, or, at very low salt concentration, increases slightly. The data are interpreted in terms of a two-step mechanism.

The bulk of the existing evidence concerning direct nucleophilic displacement reactions at dicoordinated sulfur is adequately fitted by a synchronous bimolecular mechanism. The small substituent effects[1-6] and large steric effects[7] which have been measured for a variety of reactions at dicoordinated sulfur have all been taken as proof of synchronous, direct displacement similar to the SN2 mechanism for sp^3 carbon.[8]

On the other hand, a report has recently appeared[9] where evidence is presented for the formation of a metastable intermediate in nucleophilic substitution at dicoordinated sulfur. It has been suggested[9] that the intermediate can either be an ion pair or an addition complex. Moreover, the formation of addition complexes as intermediates has also been proposed by Kwart[6] in the chlorination of phenyl sulfenyl chlorides and by Trost[10] in the reaction of sulfonium salts with organolithium compounds.

However, the bulk of information pointing to a synchronous, direct displacement compared to the relatively scarce and indirect evidence for the formation of an intermediate could lead one to believe that the formation of an intermediate is never possible. While we are still pursuing a larger objective, that of finding the reasons for sulfur ambivalent behavior, we now wish to report new and conclusive evidence for the formation of an intermediate in nucleophilic substitution at dicoordinated sulfur. Part of the significant facts pertinent to this investigation have been summarized previously.[9]

Results and Discussion

The rate of reaction of *p*-nitrobenzenesulfenyl chloride, Ar'SCl, with aniline, ArNH$_2$, was measured in

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(1) J. L. Kice and J. M. Anderson, *J. Org. Chem.*, **33**, 3331 (1968).

(2) A. Ceccon and A. Fava, unpublished data cited in ref 3.

(3) E. Ciuffarin and A. Fava, *Progr. Phys. Org. Chem.*, **6**, 81 (1968).

(4) L. Di Nunno, G. Modena, and G. Scorrano, *Ric. Sci.*, **36**, 825 (1966).

(5) C. Brown and D. R. Hogg, *Chem. Commun.*, 38 (1967).

(6) E. N. Givens and H. Kwart, *J. Amer. Chem. Soc.*, **90**, 378, 386 (1968).

(7) A. Fava and A. Iliceto, *ibid.*, **80**, 3478 (1958).

(8) Data by L. Senatore, E. Ciuffarin, and A. Fava, *ibid.*, **92**, 3035 (1970), from our own laboratory regarding the Brønsted coefficients for both entering and leaving group are also consistent with a SN2 mechanism.

(9) E. Ciuffarin and G. Guaraldi, *ibid.*, **91**, 1745 (1969).

(10) B. M. Trost, R. LaRochelle, and R. C. Atkins, *ibid.*, **91**, 2175 (1969).

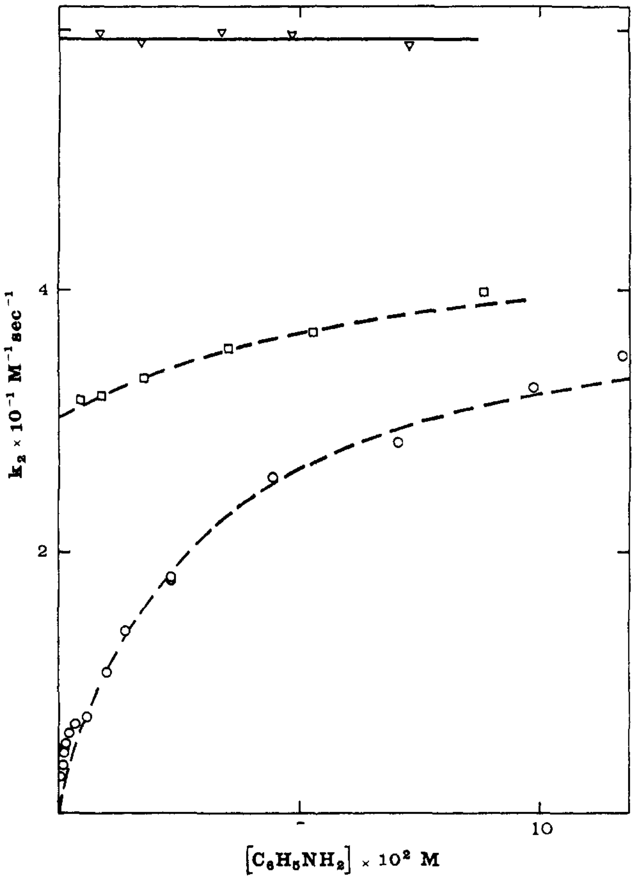

Figure 1. Pseudo-second-order rate constants for the reaction of *p*-nitrobenzenesulfenyl chloride with aniline: ○, in absence of additives; □, $[Bu_4NClO_4] = 0.625 \times 10^{-4}$ *M*; ▽, $[Bu_4NClO_4] = 2.01 \times 10^{-4}$ *M*.

benzene at 20°. Ar′SCl reacts quantitatively with $ArNH_2$ according to eq 1.

$$Ar'SCl + 2ArNH_2 \longrightarrow Ar'SNHAr + ArNH_3Cl \qquad (1)$$

In all kinetic runs the concentration of Ar′SCl was about $2\text{–}3 \times 10^{-5}$ *M*. The amine concentration ranged from 4×10^{-4} to 1.2×10^{-1} *M* (300-fold). At low amine concentration autocatalysis was observed due to the catalytic effect of the product aniline hydrochloride. Thus, under these circumstances, only initial rates were measured. However, when the amine concentration is higher than 1×10^{-2} *M* the catalytic effect of the salt is negligible and linear first-order plots are obtained. The catalytic effect of amine hydrochlorides was previously discussed[9] in detail for the reaction between tritylsulfenyl chloride and *n*-butylamine in benzene and interpreted mostly as base catalysis.

The experimental data tabulated in Table I clearly show that the pseudo-second-order rate coefficient, $k_2 = k'/[ArNH_2]$, where k' is the pseudo-first-order rate constant, depends in a nonlinear fashion on the amine concentration and tends to a limiting value as can be seen from the lower curve of Figure 1. These data are in accord with mechanism 2 which assumes the formation of an intermediate along the reaction path. In

$$Ar'SCl + ArNH_2 \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} \text{intermediate} \xrightarrow[k_N]{ArNH_2} \text{products} \qquad (2)$$

fact, steady-state treatment of such a mechanism yields eq 3 which is the equation of a curve, with k_2 approaching k_1 at increasing amine concentration.

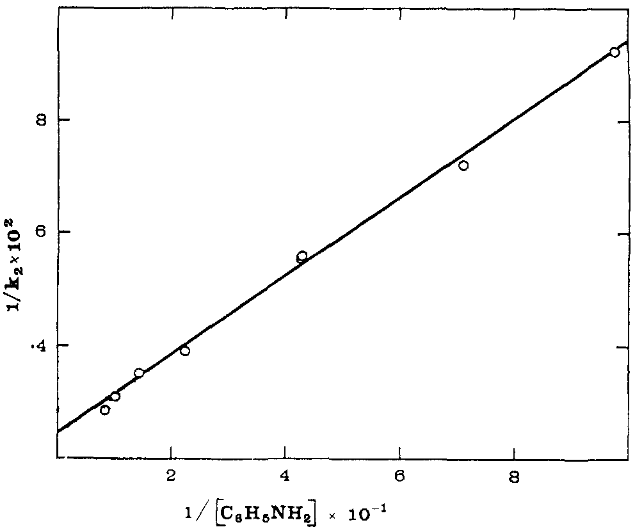

Figure 2. Plot of the inverse of the pseudo-second-order rate constants *vs.* the inverse of the amine concentration.

$$k_2 = \frac{k_1k_N[ArNH_2]}{k_{-1} + k_N[ArNH_2]} \qquad (3)$$

By reversing eq 3, eq 4 results. Thus, by plotting $1/k_2$ *vs.* $1/[ArNH_2]$

$$\frac{1}{k_2} = \frac{1}{k_{-1}} + \frac{k_{-1}}{k_1k_N}\frac{1}{[ArNH_2]} \qquad (4)$$

a straight line should be obtained with intercept $1/k$ and slope k_{-1}/k_1k_N. The data obtained for the runs which do not display autocatalysis have been plotted in this fashion (Figure 2). From the intercept and the slope calculated by applying the least-squares approximation (correlation coefficient, $r = 0.998$)[11] the following values have been determined: $k_1 = 41.43$ M^{-1} sec^{-1}, $k_N/k_{-1} = 34.45$ M^{-1}. By inserting the

Table I. Pseudo-First-Order Rate Constant (k') and Pseudo-Second-Order Rate Coefficient ($k_2 = k'/[ArNH_2]$) for the Reaction between *p*-Nitrobenzenesulfenyl Chloride[a] and Aniline

$[ArNH_2] \times 10^3$ *M*	$k' \times 10^2$, sec^{-1}	k_2, M^{-1} sec^{-1}
0.393	0.112[b]	2.85
0.786	0.276[b]	3.51
0.997	0.464[b]	4.65
1.128	0.578[b]	5.13
1.41	0.743[b]	5.27
2.35	1.43[b]	6.08
3.14	2.12[b]	6.74
5.71	4.18[b]	7.30
10.24	11.07	10.81
14.1	19.5	13.87
23.4	41.9	17.86
23.5	42.4	18.05
44.3	113.55	25.60
70.5	199.6	28.31
98.4	319.7	32.50
117.5	411.9	35.05

[a] The substrate's concentration was about $2\text{–}3 \times 10^{-5}$ *M*.
[b] Initial rate.

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[11] H. S. Mickley, T. K. Sherwood, and C. E. Reed, "Applied Mathematics in Chemical Engineering," 2nd ed, McGraw-Hill, New York, N. Y., 1957, Chapter 2.

values thus found in eq 3 the lower dashed line of Figure 1 was computed. The fit to the experimental data is quite good even though the points at lower amine concentration all lie slightly above the calculated line. However, this is consistent with the procedure which has been used to deduce the initial rates in the autocatalytic runs. The value of k_2 has been, in fact, determined from the slope of the tangent line at zero time. This visual procedure is strongly influenced by the points of the curve which have already experienced autocatalysis, thus leading to higher values of the rate.

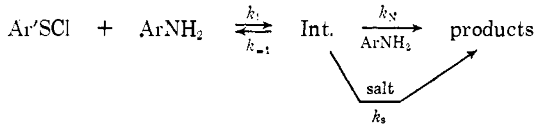
The rate of reaction between Ar'SCl and $ArNH_2$ was measured also in the presence of Bu_4NClO_4. The data are reported in Table II. Good linear pseudo-first-order plots were obtained. Bu_4NClO_4 exerts a strong accelerating effect on the reaction rate in accord with what has been previously found for the reaction of tritylsulfenyl chloride with *n*-butylamine in the same solvent medium.[9] This effect has been explained as a combination of medium and specific effects.[12] The data presented in this paper strongly support such a view. In fact, a simple medium effect should not change the general form of the curve which has been obtained in the absence of salt but should increase the rate for all points of the curve by roughly the same relative amount. On the contrary, addition of salt drastically changes the form of the curve and a definite intercept appears. At relatively high salt concentrations the second-order rate constant is independent of the amine concentration (higher plot of Figure 1), while at lower salt concentrations k_2 still depends slightly on the concentration of aniline (middle plot of Figure 1). This is clearly a specific salt effect, where Bu_4NClO_4 enters the rate equation. The fact that a medium effect is also operative will be shown shortly.

Table II. Rate Constants in the Presence of Tetra-*n*-butylammonium Perchlorate[a]

$[ArNH_2] \times 10^2$ M	$Bu_4NClO_4 \times 10^4$ M	k', sec^{-1}	k_2, M^{-1} sec^{-1}
0.44	0.625	0.139	31.6
0.88	0.625	0.281	31.9
1.76	0.625	0.585	33.2
3.52	0.625	1.25	35.5
5.27	0.625	1.93	36.7
8.80	0.625	3.51	39.9
0.847	2.01	0.505	59.7
1.69	2.01	0.999	59.0
3.38	2.01	2.027	59.8
4.82	2.01	2.866	59.5
7.26	2.01	4.276	58.9

[a] The substrate's concentration was about 2–3 × 10^{-5} M.

All the data, both in the absence and in the presence of Bu_4NClO_4, can be easily interpreted by the overall mechanism 5. Steady-state treatment of mechanism 5



$$\begin{tikzcd}[column sep=large] \mathrm{Ar'SCl} + \mathrm{ArNH_2} \arrow[r, shift left, "k_1"] & \mathrm{Int.} \arrow[l, shift left, "k_{-1}"] \arrow[r, "k_{\mathrm{N}}", "\mathrm{ArNH_2}"'] \arrow[r, bend right=60, "\mathrm{salt}", "k_{\mathrm{s}}"'] & \text{products} \end{tikzcd} \qquad (5)$$

yields eq 6. Inspection of eq 6 shows that (a) in the

$$k_2 = \frac{k_1(k_{\mathrm{N}}[\mathrm{ArNH_2}] + k_{\mathrm{s}}[\mathrm{salt}]^m)}{k_{-1} + k_{\mathrm{N}}[\mathrm{ArNH_2}] + k_{\mathrm{s}}[\mathrm{salt}]^m} \qquad (6)$$

absence of salt, eq 6 simplifies to eq 3; (b) when the concentration of salt is sufficiently high, k_2 is independent of the concentration of amine, $k_2 = k_1$, since $(k_{\mathrm{N}}[\mathrm{ArNH_2}] + k_{\mathrm{s}}[\mathrm{salt}]^m) \gg k_{-1}$; (c) at lower salt concentration a plot of k_2 *vs.* the amine concentration is a curve with a definite intercept at zero amine concentration.

The mechanism proposed is so completely in accord with the data that the formation of an intermediate in this and similar reactions must now be regarded as well substantiated. We had already presented some evidence[6] that reactions of sulfenyl derivatives with amines in benzene are catalyzed by added bases or the nucleophile itself and proceed by an intermediate complex mechanism. However, we were not in a position to exclude altogether a mechanism which would assume the previous formation of an amine dimer or of amine–base adducts as exemplified by eq 7, where B can be any

$$\begin{aligned} &\mathrm{ArNH_2} + \mathrm{B} \overset{K_{\mathrm{D}}}{\rightleftarrows} [\mathrm{ArNH_2}\text{---}\mathrm{B}] \\ &\mathrm{Ar'SCl} + [\mathrm{ArNH_2}\text{---}\mathrm{B}] \xrightarrow{k_{\mathrm{D}}} \text{products} \end{aligned} \qquad (7)$$

molecule of present base. This type of mechanism, in fact, presents in many instances kinetic features similar to those of the intermediate complex mechanism (eq 3). An analogous situation arises in nucleophilic substitutions at carbon where the kinetic data alone do not permit a clear choice between an intermediate complex mechanism or a mechanism with formation of dimer or adducts (similar to mechanism 7). As far as sp^3 or carbonyl carbon are concerned, a number of authors adopt the latter view.[13] An attempt to interpret the data of this paper in terms of synchronous displacement on sulfur with an amine dimer as nucleophile would lead to highly improbable conclusions. The concentration of dimer, N_2, at any stoichiometric amine concentration, N_s, can be calculated from $K_{\mathrm{D}} = [N_2]/(N_s - 2[N_2])^2$, where K_{D} is the equilibrium constant for dimer formation. The rate law should then be: $k' = k_{\mathrm{D}}[N_2]$. In this case a plot of k' *vs.* $[N_2]$ should yield a straight line of slope k_{D} and zero intercept. A linear relation can be perceived by plotting the data of Table I in such fashion. However, this is possible only by assuming a value for the equilibrium constant for dimer formation of about 50 M^{-1}. If this value were correct, aniline would be dimerized to the extent of about 40% at a stoichiometric concentration of 10^{-2} M. Moreover, it has been found that for *m*-chloroaniline,[14] a structurally similar amine, $K_{\mathrm{D}} = 0.5$ M^{-1}, a value about 100 times smaller.

Catalysis by Bu_4NClO_4 has been discussed in detail[9] for the reaction between tritylsulfenyl chloride and *n*-butylamine where more data pertinent to the salt effect could be obtained. In the present system the combination of specific and medium effects makes it impossible to calculate the order in salt. In fact, at a concentration in Bu_4NClO_4 as low as 2 × 10^{-4} M the second-order rate constant, k_2, is independent (see above) of the concentration of salt, so that further ad-

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(12) The nature of the specific effect is dealt with at the end of the Discussion.

(13) See, for example: (a) R. F. Hudson and I. Stelzer, *J. Chem. Soc. B*, 775 (1966); (b) D. N. Kevill and S. Posselt, *Chem. Commun.*, 438 (1967); (c) F. M. Menger, *J. Amer. Chem. Soc.*, **88**, 3081 (1966).

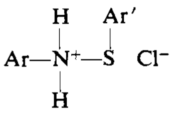
(14) J. L. Mateos, R. Cetina, and O. Chao, *Chem. Commun.*, 519 (1965).

dition of salt can only affect k_1 because of a change in the polarity of the medium. However, the analogy between the two reactions is so close it can be safely assumed that the order in Bu_4NClO_4 is 0.5 in both cases.

The dashed line of the middle plot of Figure 1 has been calculated from eq 6. The appropriate values of $k_1 = 46.0$, $k_N/k_{-1} = 40.0$, and $k_N/k_s[\text{salt}]^m = 21.0$ have been found by trial and error. The number of points is too small to attach any precision to the calculated constants. However, the values thus found are consistent with those determined both in the absence of added salt, $k_1 = 41.43$, and at high concentration of added salt, $k_1 = 59.4$. A regular increase of this magnitude in the rate constant for the formation of the intermediate is in accord with the type of transition state demanded by the reaction, *i.e.*, one involving separation of charge. The larger value of k_N/k_{-1} compared to that measured in the absence of added salt (34.45) is also consistent with the proposed mechanism. In fact, k_N should be slightly greater and k_{-1} smaller when the polarity of the medium is increased.

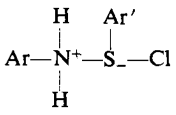
The preceding discussion served to demonstrate that the data can be interpreted only by a two-step mechanism. However, two details of the mechanism have not been discussed yet: (a) the type of intermediate involved and (b) the specific role of Bu_4NClO_4.

As we mentioned earlier,[9] two types of intermediates can be envisioned: either an ion pair (I) or an addition complex (II) formed through the use of sulfur d



$$Ar{-}\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{N^+}}{-}\overset{\overset{Ar'}{|}}{S}\quad Cl^-$$

I

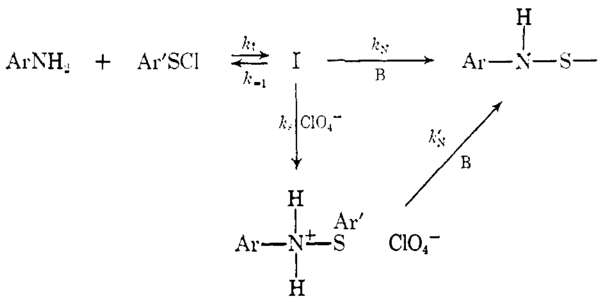


$$Ar{-}\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{N^+}}{-}\overset{\overset{Ar'}{|}}{S_-}{-}Cl$$

II

orbitals. At the present time it is not yet possible to choose with confidence between the two formulations.

As far as the specific role of Bu_4NClO_4 is concerned, two types of catalysis can be suggested: (a) a process analogous to that involved in the special salt effect observed in certain solvolyses[15] and (b) base catalysis. If in our system the special salt effect were operative, the intermediate could only be the ion pair I, and the overall mechanism would be that described by eq 8, where the ion pair I is formed in a fast equilibrium and is then either converted to products by removal of a proton by a base or, alternatively, to the perchlorate ion pair III, which, because of the extremely low nucleophilicity of ClO_4^-, cannot revert to amine and sulfenyl derivative and can only go to products. While there is ample precedent in the literature concerning carbonium ions for perchlorate ion to act in the way described above, we know of only one example where the special salt effect has been postulated for reactions of sulfenyl derivatives, *i.e.*, the chlorination of sulfenyl chlorides in acetic acid[6] where both ion pairs and addition complexes have been postulated. In our system the presence of the special salt effect would probably mean that the first step of eq 8 is a synchronous SN2 displacement at sulfur.



(8)

In a previous paper[9] we have studied the effect of both Bu_4NClO_4 and Bu_4NCl in the reaction between tritylsulfenyl chloride and butylamine in benzene. The two salts present a great similarity of behavior. Since the chloride can only act as a general base, the role of the perchlorate could also be viewed as that of a catalyst base. The perchlorate has never been found to act as a base except perhaps by Kevill[16] in the methanolysis of methyl perchlorate in benzene. Kevill suggests that the perchlorate accelerates the methanolysis because ClO_4^- increases the nucleophilicity of the alcohol through H bonding with the proton of methanol. The fact that in nucleophilic substitution at sulfur the catalytic efficiency of the chloride is only slightly greater than that of the perchlorate[9] is not sufficient to exclude base catalysis by perchlorate even though perchlorate ion is certainly much less basic than chloride ion. That would only mean that the Brønsted coefficient for catalysis by negative ions is very small. This hypothesis is corroborated by the experimental fact that for the same reaction[9] the catalytic efficiency of various nitrogen bases is almost the same with a Brønsted coefficient smaller than 0.1. This very small value would mean that the intermediate is very reactive and thus barely discriminatory toward different bases. The fact that negative ions are more efficient bases than neutral amines, the little discriminating character of the catalysis notwithstanding, could be explained by the fact that they act on the part of the intermediate which is positively charged and this favors the collision in the appropriate site of the intermediate of negatively charged particles. This is especially so in a low polarity solvent where the charge of the ions is not screened by the solvent. In the hypothesis that the perchlorate acts as a general base, the intermediate can be described by either one of the above two formulations (I or II).

Experimental Section

Materials. 4-Nitrobenzenesulfenyl chloride, mp 50–51°, was prepared from 4-nitrophenyl disulfide by known procedures.[17] Aniline was a commercial product which was twice distilled from potassium hydroxide pellets (90° (15 mm)). Benzene was refluxed over Na-K alloy and fractionated. The preparation of tetra-*n*-butylammonium perchlorate, mp 213°,[18] was described previously.[9]

N-Phenyl-*p*-nitrobenzenesulfenamide. To 1.1 g of *p*-nitrobenzenesulfenyl chloride in benzene, a solution of 1.15 g (5% excess) of aniline in benzene was added while stirring. The mixture was washed several times with water and dried over anhydrous sodium sulfate. Evaporation of the solvent yielded a deep yellow oil. Upon addition of a small amount of dry ethyl ether a clear solution was obtained which was kept at −15° for a few days until a yellow solid accumulated. This was twice recrystallized, mp 69–70°. The ir spectrum shows a narrow band at 3300 cm^{-1} which corre-

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[15] S. Winstein, P. E. Klinedinst, and G. C. Robinson, *J. Amer. Chem. Soc.*, **83**, 885 (1961).

[16] D. N. Kevill and H. S. Posselt, *Chem. Commun.*, 438 (1967).

[17] (a) F. Montanari, *Gazz. Chim. Ital.*, **86**, 406 (1956); (b) T. Zincke, *Justus Liebigs Ann. Chem.*, **400**, 9 (1913).

[18] M. B. Reynolds and C. A. Kraus, *J. Amer. Chem. Soc.*, **70**, 1709 (1948).

sponds to the N–H stretching vibration. The uv spectrum has a maximum at 325 mμ with ε 12,060 in benzene.

Anal. Calcd for $C_{12}H_{10}N_2O_2S$: C, 58.52; H, 4.09; N, 11.38; S, 13.02. Found: C, 58.4; H, 4.04; N, 11.5; S, 13.15.

Kinetics. The rate of reaction was followed at 350-mμ with a Durrum stopped-flow spectrophotometer.[19] The experimental infinity point was identical with that calculated from the extinction coefficient of the product sulfenamide. In two cases the whole spectrum of the solution at the infinity point was recorded with a Unicam recording spectrophotometer. The spectrum was identical with that of the sulfenamide at the same concentration.

Aniline and *p*-nitrobenzenesulfenyl chloride were kept in a dessicator, at 0° in the dark.

Due to the high lability of *p*-nitrobenzenesulfenyl chloride in the presence of traces of moisture, particular care was taken in the preparation of the solutions of the reagents. Benzene was distilled immediately before use and the solutions were prepared in a drybox and used immediately.

Acknowledgment. This investigation was supported by C.N.R., Rome. Thanks are due to E. N. I., Rome, for the loan of a stopped-flow spectrophotometer.

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[19] For a description of the apparatus and treatment of the kinetic data see: G. Tomalin, M. Trifunac, and E. T. Kaiser, *J. Amer. Chem Soc.*, **91**, 722 (1969).

Alkaloid Studies. LXIII.[1] The Constitution and Chemistry of Dichotine and 11-Methoxydichotine[2]

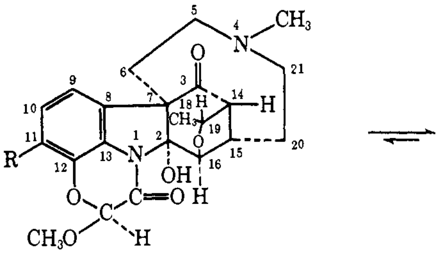
Nicholas C. Ling[3] and Carl Djerassi

Contribution from the Department of Chemistry, Stanford University, Stanford, California 94305. *Received March 16, 1970*

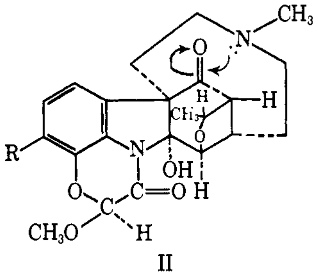
Abstract: The constitution of two closely related indole alkaloids, dichotine (Ia) and 11-methoxydichotine (Ib), isolated from the Peruvian *Apocynaceae*, *Vallesia dichotoma* Ruiz *et* Pav, was investigated with the help of infrared, ultraviolet, nuclear magnetic resonance, and mass spectroscopy as well as chemical degradations and isotopic labeling. During the course of the investigation, many new and interesting reactions were discovered. A theoretically plausible biogenetic route leading to these two unusual alkaloids is discussed.

The Peruvian plant, *Vallesia dichotoma*[4] Ruiz *et* Pav (family, *Apocynaceae*), is one of the richest sources of new indole alkaloids. This feature was documented in several papers published from our laboratories[5-10] starting in 1959. The latest paper[1] describes the X-ray crystallographic structure determination of two more novel indole alkaloids, dichotine and 11-methoxydichotine,[11] isolated from this plant. We should now like to report the structural investigation and interesting chemistry of these two alkaloids, which chronologically preceded the X-ray studies.[1]

(+)-Dichotine (Ia[12]) and (+)-11-methoxydichotine (Ib) are present in approximately 0.001% yield in the bark of *Vallesia dichotoma*. Both alkaloids have identical R_f values in many solvent systems but they were finally separated by tlc. A total of approximately 1.5 g of the alkaloid mixture was available for the structural work.



Ia, R = H
Ib, R = CH₃O



II

Microanalysis[8] and high-resolution mass spectrometric measurement showed molecular compositions of $C_{22}H_{26}N_2O_6$ and $C_{23}H_{28}N_2O_7$ for Ia and Ib, respectively, the difference being attributed to a methoxyl unit on the benzene ring of Ib, as evidenced by nmr and mass spectrometry.

The nmr spectrum (Figure 1) of dichotine (Ia) had the following characteristic features: a secondary methyl doublet (H^p) at δ 0.60 (J = 6.0 cps); a broad one-proton triplet at δ 1.76 (J = 14.0, 14.0 cps); a methyl singlet (H^l) at δ 2.02 which was assigned to an N-methyl signal because of its shift to δ 3.26 in trifluoroacetic acid; a complicated eight-proton signal between δ 2.10 and 3.02 with a distinct one-proton

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[1] For paper LXII see N. C. Ling, C. Djerassi, and P. G. Simpson, *J. Amer. Chem. Soc.*, **92**, 222 (1970).

[2] Taken from the Ph.D. Thesis (1969) of N. C. L. Financial support from the National Institutes of Health (Grant No. GM-11309) of the U. S. Public Health Service is gratefully acknowledged.

[3] Stauffer Predoctoral Fellow, 1965–1966.

[4] The plant material was collected by Mr. Juan A. Brissolese near Ica, Peru, at 300 m.

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