can be seen that the rate[8] of chlorination with NCS is very slow. The products formed were 5-chloro-, 7-chloro-, and a trace of 5,7-dichloro-8-quinolinol, and the orientation of the chlorine atom favored the 7 position over the 5 position by a ratio of about 4:1. The concentration of halogenating agent did not appear to affect the rate of reaction, but raising the temperature from ambient to 40–60° caused about a threefold increase in rate of chlorination. Bromination with NBS yielded three products in significant quantities, 5-bromo-, 7-bromo-, and 5,7-dibromo-8-quinolinol. The rate of bromination appeared to be rapid, as evidenced by no apparent effect due to temperature change, and on increasing the ratios of halogenating agent to 8-quinolinol, only the dibromo derivative was formed. The formation of 7-bromo-8-quinolinol was about four times that of the 5-bromo analog. The bromination of 8-quinolinol in the 7 position by N-bromo compounds has also been observed by Pearson, *et al.*,[9] and reexamined by Gershon, *et al.*[2] Iodination of 8-quinolinol with NIS yielded essentially two iodination products. 5-Iodo-8-quinolinol was the major product and 5,7-diiodo-8-quinolinol was formed in minor quantities. An increase in reaction temperature increased the rate of iodination of 5-iodo-8-quinolinol to yield a greater proportion of the 5,7-diiodo derivative than obtained at ambient temperatures.

A comparison of these results with the data previously reported on the halogenation of bis(8-quinolinolato)copper(II) with N-halosuccinimides[2] shows that, on chlorination of 1 equiv of ligand with 1 equiv of NCS, a high per cent of chelate was chlorinated, whereas very little free ligand was chlorinated. These results are in agreement with the conclusion of Hix and Jones,[5] that chelation with metals increases the rate of halogenation of 8-quinolinol. Comparable halogenations with NBS and NIS were not amenable to drawing conclusions as to the effect of chelation on rate of halogenation.

The orientation of the substituents of the monohalogenated products of the free ligand as compared with the chelate was unexpected. The chlorination products of 8-quinolinol consisted of about four times as much 7-chloro-8-quinolinol as 5-chloro isomer, and, on chlorination of the copper(II) chelate of 8-quinolinol, 5- and 7-chloro-8-quinolinols formed in about equal yield. The monobromination products of the free ligand consisted of 7-bromo and 5-bromo-8-quinolinols, also in the ratio of 4:1, but monobromination of the chelate yielded 80% 5-bromo-8-quinolinol and no detectable 7 isomer. The monoiodination products of the free ligand yielded 94% 5-iodo-8-quinolinol, whereas the chelate yielded 90% 7-iodo-8-quinolinol and 10% 5-iodo analog.[10] This is consistent with the hypothesis of Maguire and Jones[4] and Hix and Jones[5] that chelation

of a ligand with a metal does not change the reactive positions of an aromatic compound toward electrophilic substitution. However, it is obvious that chelation does affect orientation of substituents in electrophilic substitution with N-halosuccinimide.

Experimental Section[11]

Halogenation of 8-Quinolinol with N-Halosuccinimides.—To a solution of 1 mmol of 8-quinolinol in 10 ml of chloroform was added 1, 2, or 3 mmol of the respective N-halosuccinimide. The mixture was stirred on a magnetic stirrer hot plate for 3 hr keeping the volume nearly constant by addition of chloroform, as needed. The hot plate was set to maintain temperatures of 40–60°. At the end of the reaction period, the solution was washed with three 5-ml portions of an aqueous solution containing 5% NaOAc and 5% NaHSO₃ in order to destroy unused N-halosuccinimide and to remove the succinimide formed. A portion of the chloroform solution was evaporated under a stream of air, and the residue was dissolved in acetonitrile. The quinolinols were converted to the trimethylsilyl derivatives by means of N,O-bis(trimethylsilyl)acetamide by the method of Klebe, *et al.*,[12] and chromatographed.

(11) Gas chromatography was performed on a Varian Aerograph Model 1200 gas chromatograph with a flame ionization detector to which was attached a Varian Aerograph Model 20 recorder. The column and conditions employed for the gas chromatographic separation of the chloro- and bromo-8-quinolinols were previously described.[2] To assay the iodo-8-quinolinols, a stainless steel column, 5 ft × 0.125 in. o.d., was packed with 1% Apiezon L coated on 80–100 mesh acid washed Chromosorb W, previously treated with dimethyldichlorosilane. The instrument was operated at a column starting temperature of 150° which was programmed at 6°/min to 250°. The injector and detector temperatures were maintained at 200 and 250°, respectively, while the flow rate of nitrogen was 22 ml/min. Retention times for 8-quinolinol and the 5-iodo, 7-iodo, and 5,7-diiodo derivatives were 1.7, 5.8, 6.2, and 11.8 min, respectively.

(12) J. F. Klebe, H. Finkbeiner, and D. M. White, *J. Amer. Chem. Soc.*, **88**, 3390 (1966).

The Reaction of Indole with N-Chloropyrrolidine and N-Chlorodibutylamine[1]

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Evidence is accumulating from recent developments in the chemistry of haloamines[2] which indicates that their reactions with organic substrates involve the intermediacy of electrophilic nitrogen species in either free-radical[3,4] or ionic[5] mechanisms. On this basis we have studied the reaction of indole with N-chloropyrrolidine (1) and N-chlorodibutylamine (2) with the hope that attack by electrophilic nitrogen intermediates would yield 3-aminoindole derivatives. Our results

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(8) The term "rate" is used in the sense of percent halogenated 8-quinolinol formed during the 3-hr reaction time.

(9) D. E. Pearson, R. D. Wysong, and C. V. Breder, *J. Org. Chem.*, **32**, 2358 (1967).

(10) It should be noted that our previous report[2] indicated that 99% 7-iodo-8-quinolinol was formed on iodination of bis(8-quinolinolato)copper-(II) with NIS. That assay was obtained by gas chromatography using a 5% QF-1 column. Later work showed that mixtures composed of 10% or less of one of the monoiode-8-quinolinols in the presence of 90% of the other could hot be resolved even though mixtures of more nearly equal proportion could be assayed. The ir spectra of mixtures, composed of overwhelming proportions of one isomer, masked the presence of the other. The present work was carried out with a 1% Apiezon L column which can resolve mixtures of 5- and 7-iodo-8-quinolinols in all proportions.

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(1) Support from the Department of University Affairs, Province of Ontario, is gratefully acknowledged.

(2) P. A. S. Smith, "The Chemistry of Open-Chain Organic Nitrogen Compounds," Vol. 1, W. A. Benjamin, New York, N. Y., 1965, p 192 ff.

(3) F. Minisci, G. P. Gardini, and F. Bertini, *Can. J. Chem.*, **48**, 544 (1970).

(4) J. Spanswick and K. U. Ingold, *ibid.*, **48**, 546 (1970), and references cited therein; J. Spanswick and K. U. Ingold, *ibid.*, **48**, 554 (1970).

(5) P. G. Gassman, *Accounts Chem. Res.*, **3**, 26 (1970).

Chloramine	Entry	Conditions	Product	% yield[a]
(1)	A	HOAc, H_2SO_4, 0°, 1 hr, N_2	3	44
	B	HOAc, H_2SO_4, $h\nu$, 35°, 2.5 hr	3	Trace
	C	Ether, $h\nu$, 35°, 17 hr	4	23[b]
	D	CH_3NO_2, H_2SO_4, 0°	3	26
	E	PE[c]–benzene, room temp, dark, 1 day	4	36[b]
	F	CH_3CN, room temp, dark, 2 days	4	50
	G	MeOH, $AgNO_3$, reflux, 4.5 hr	4	22
	H[d]	Toluene, $AgBF_4$, room temp, dark, 1 day	4	10
$(n-C_4H_9)_2NCl$ (2)	I	PE[c]–benzene, room temp, dark, 3 days	4	51
	J	CH_3CN, room temp, dark, 3 days	4	8

[a] Based on reacted indole. [b] Glc analysis. [c] Petroleum ether. [d] We thank K. S. Bhandari for this experiment.

reported herein show, however, that the chloramines act mainly as electrophilic chlorinating agents[2] in reactions with indole under a variety of conditions. Analogous behavior has been found recently in the reaction of indole with N,N-dichlorourethan.[6,7] Nevertheless, our work provides a facile alternate synthesis of 3-chloroindole (4).[8]

The results are summarized in Table I. The application of the strongly acidic Hofmann–Loeffler–Freytag conditions[4] to the reaction of indole with 1 gave poor yields of 3,3-dichlorooxindole (3) (entries A, B, and D) in agreement with the known ready oxidizability of indole by such reagents.[9] Treatment of indole with 1 in the presence of silver salts under conditions which are known to generate nitrenium ions[5] gave poor yields of 4, irrespective of the nature of the anion (entries G and H). Finally, when the reaction was carried out in the absence of metal or acidic catalysts in the dark for extended periods of time, fair to good yields of 4 were obtained (entries E and F). The lower yield of 4 obtained in the reaction of indole with N-chlorodibutylamine (2) in acetonitrile (entry J) is due to the decomposition of 2 to n-dibutylamine hydrochloride (30%) in the more polar solvent.

3   4
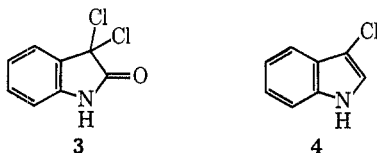
Experimental Section

Melting points were determined on a Fisher-Johns apparatus and are uncorrected. Infrared spectra were recorded with a Beckman IR-5 spectrophotometer. Ultraviolet spectra were obtained with a Beckman DB-G spectrophotometer. A Jeol C-60 instrument was used for recording nmr spectra. Gas–liquid chromatography (glc) was carried out on an Aerograph Autoprep Model 700 with a 10 ft × $^3/_8$ in. column of 10% SE-30 silicone gum rubber on 60–80 mesh Chromosorb W. The photolyses were performed in a Rayonet Reactor in quartz vessels using 3500 Å lamps. Silica gel (Brinkmann, 0.05–0.20 mm) was used for chromatography. Reagent grade acetonitrile and methanol were used without further purification. Reagent grade benzene and petroleum ether (60–80°) were dried and distilled before use.

(6) T. A. Foglia and D. Swern, *J. Org. Chem.*, **33**, 4440 (1968).
(7) J. M. Muchowski, *Can. J. Chem.*, **48**, 422 (1970). We thank Dr. Muchowski for a preprint and for discussion.
(8) J. C. Powers, *J. Org. Chem.*, **31**, 2627 (1966).
(9) R. L. Hinman and E. R. Shull, *ibid.*, **26**, 2339 (1961); G. F. Smith and A. E. Walters, *J. Chem. Soc.*, 940 (1961).

Reaction of Indole with N-Chloropyrrolidine (1). A. In Sulfuric Acid–Acetic Acid.—A mixture of 4.4 ml of 98% sulfuric acid and 15 ml of glacial acetic acid was stirred under nitrogen in an ice bath for 10 min. An ethereal solution of 1 (9 ml, 9 mmol) was then added and stirring was continued for another 15 min. Indole (1.05 g, 9 mmol) was added in small portions and the resulting green mixture was stirred for 1 hr. It was then poured into 200 ml of ice water and extracted with chloroform. The chloroform extracts were washed with water and dried ($MgSO_4$). Evaporation of solvent gave 3,3-dichlorooxindole (3), 0.8 g (44%), which was characterized by identical ir, nmr, melting points, and mixture melting point with an authentic sample.[10]

B. In Acetonitrile.—A mixture of 560 mg (4.8 mmol) of indole in 10 ml of acetonitrile and 8 ml (4.8 mmol) of 1 in ether was stirred at room temperature in the dark for 2 days. The solvent was evaporated and the resulting residue was dissolved in methylene chloride and washed three times with saturated sodium bicarbonate solution. The methylene chloride extract yielded after drying (Na_2SO_4) 990 mg of an oil which was chromatographed. Elution with petroleum ether–benzene (1:1) followed by sublimation gave 386 mg (50%) of 4.

A blank run showed that 1 was stable under the above conditions for at least 5 days as determined by sodium thiosulfate titration.

(10) A. Hantzsch, *Ber.*, **54B**, 1221 (1921).


Synthetic Reactions by Complex Catalysts.
XVIII. The Reaction of Azide with Isocyanide by Iron Carbonyl Catalyst.
A New Route to Carbodiimide

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This note describes the iron carbonyl catalyzed reaction of an azide with isocyanide, which provides a new method for the preparation of the unsymmetrical carbodiimide (eq 1). In the absence of catalyst, no reac-

$$RN_3 + R'N{\equiv}C: \xrightarrow{\text{catalyst}} R{-}N{=}C{=}N{-}R' + N_2 \quad (1)$$

I   II   III
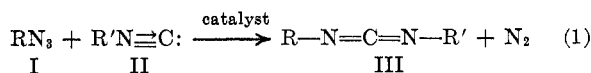
tion occurs; azide and isocyanide were recovered almost quantitatively from the reaction system. In the

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