removed by filtration and the ether evaporated. Two fractions were obtained from the residue, one boiling at 60–61° (4 mm.) and the other at 122–123° (4 mm.). The second fraction solidified on standing to colorless crystals which melted at 52–53° and proved to be N-methyl-*o*-styrylcyanamide. The yield was 0.75 g. (24%).

Anal. Calcd. for $C_{10}H_{10}N_2$: N, 17.72; mol. wt., 158. Found: N, 17.65; mol. wt., 156.

Mixed Melting Point Determinations.—The various mixtures of the quinoline dicyanides were prepared by dissolving weighed amounts of the two isomers in purified ether, allowing the ether to evaporate at room temperature and heating the residue at 60° for 3 minutes. The melting points were determined in capillary tubes heated in a Hershberg melting point apparatus.[10]

Molecular Refraction Determinations.—Densities were determined at 20° using a 10-cc. calibrated pycnometer. The refractive indices were measured at 20° with an Abbe refractometer. For the purified bromobenzene used as a solvent, d^{20}_4 1.492 and $n^{20}D$ 1.560 from which MrD 34.03 cc. A solution of 0.3521 g. of the low-melting isomer in 10.46 g. of bromobenzene gave d^{20}_4 1.486 and $n^{20}D$ 1.561 from which $MrD_{app.}$ 45.4 cc. for the compound. A solution of 0.3540 g. of the high-melting isomer in 16.85 g. of bromobenzene gave d^{20}_4 1.490 and $n^{20}D$ 1.560 from which $MrD_{app.}$ 42.9 cc.

Absorption Spectra.—The ultraviolet absorption spectra were determined with a Beckman model DU spectrophotometer. The solvent was 95% ethyl alcohol and the concentrations were between 10^{-4} and 10^{-5} molar. The slit width was adjusted to the minimum value for each wave length in order to obtain the maximum amount of fine structure.

(10) Hershberg, *Ind. Eng. Chem., Anal. Ed.*, **8**, 312 (1936).

Summary

Molecular refractions and ultraviolet absorption spectra indicate that the isomeric quinoline dicyanides are structural isomers rather than stereochemical isomers. A comparison of the spectra of the two dicyanides with those of phenylcyanamide, N-methylphenylcyanamide, and N-methyl-*o*-styrylcyanamide indicates that the low-melting isomer is 1,2-dicyano-1,4-dihydroquinoline and that the high-melting isomer is 1,2-dicyano-1,2-dihydroquinoline.

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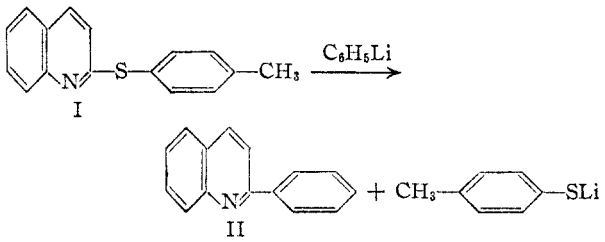
RECEIVED JULY 10, 1950

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF IOWA STATE COLLEGE]

Reactions of Some Organometallic Compounds with 2-Substituted Quinolines[1a]

BY HENRY GILMAN AND JOHN A. BEEL

As a result of some investigations into the reactions of organometallic compounds with benzothiazole,[1b] it was considered of interest to determine the effect of phenyllithium on *p*-tolyl 2-quinolyl sulfide (I), a compound which, like benzothiazole, contains the —N=C—S— grouping. The preliminary reaction gave a 57% yield of *p*-thiocresol and a 47% yield of 2-phenylquinoline (II).



I

II

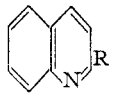
Regardless of the reaction mechanism, the over-all reaction resulted in a cleavage of the sulfide between the 2-carbon of quinoline and the sulfur atom. This suggested similar cleavage reactions with other 2-substituted quinolines and with other organometallic compounds.

In Table I are given the data on the reactions of phenyllithium with other 2-substituted quinolines. With the exceptions of 2-(N-piperidyl)-quinoline and 2-benzylquinoline, reactions similar to (1) were obtained with the production of varying amounts of 2-phenylquinoline. The yield varied from 10.6% in the case of 2-allyloxyquinoline to 70.2% in the case of 2-phenoxyquinoline. Of the organometallic compounds used, phenyllithium gave the best yields of cleavage products because it was quite reactive, but did not give extensive side reactions. 2-Chloroquinoline gave a good yield (65%) of 2-phenylquinoline, and it is interesting to note that under the same conditions 2-chlorobenzothiazole, containing a more reactive halogen atom, gave a 47.8% yield of 2-phenylbenzothiazole. Although no 2-

(1) (a) Paper LXVII in the series: The Relative Reactivities of Organometallic Compounds; the preceding paper with Webb is in THIS JOURNAL, **71**, 4062 (1949); (b) Gilman and Beel, *ibid.*, **71**, 2328 (1949).

TABLE I

REACTIONS OF PHENYLLITHIUM WITH 2-SUBSTITUTED QUINOLINES



No.	R	Yield of 2-phenyl-quinoline,[a] %	Yield of cleavage product, %	Reaction time, hr.	T, °C.	Recovery of starting material, %
1	$CH_3C_6H_4S$-	47.4	*p*-Thiocresol[b] (57)	5	28	...
2	C_6H_5O-[c]	70.2	Phenol[d] (72.3)	18	28	...
3	C_2H_5O-[e]	41.5	(Ethanol)[f]	18	28	54.8[g]
4	Cl-	65.7	.....	30	28	8.0[h]
5	$C_5H_{10}N$-	..	Piperidine (trace)	18	28	10.0[i]
6	$C_6H_5CH_2O$-[j]	12.2	Benzyl alcohol (24.8)[k]	6	0	17.0[l]
7	C_3H_5O-	10.6	(Allyl alcohol)[f]	18	28	15.6[m]
8	$C_6H_5CH_2$-	..	.....	18	28	82.6[n]

[a] Identified by m.p. (81–83°) and mixed m.p. determination with an authentic specimen. The picrate (m.p. 191°) was also identified by a mixed m.p. determination. [b] Identified by m.p. (43–45°) and mixed m.p. determination. [c] Friedländer and Ostermaier, *Ber.*, **15**, 332 (1882). [d] Identified by m.p. (41–42°) and mixed m.p. determination. [e] Bogert and May, THIS JOURNAL, **31**, 507 (1909). [f] Not isolated. [g] B.p. 74° at 0.4 mm.; $n^{20}D$ 1.5892. [h] B.p. 115° at 0.03 mm. [i] Identified by m.p. (50°) and mixed m.p. determination. [j] Prepared from 2-chloroquinoline and sodium benzyloxide. [k] B.p. 60° at 0.03 mm.; $n^{20}D$ 1.5424. Identified by m.p. of the 3,5-dinitrobenzoate and mixed m.p. determination with an authentic specimen. [l] Identified by m.p. and mixed m.p. determination. [m] B.p. 145° at 0.1 mm.; $n^{20}D$ 1.5948. [n] B.p. 170–176° at 0.1 mm.; $n^{20}D$ 1.6339–1.6370. Identified by m.p. of picrate (152–154°) and mixed m.p. determination.

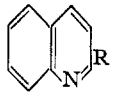
phenylquinoline was obtained from 2-(N-piperidyl)-quinoline, the recovery of 2-(N-piperidyl)-quinoline was also low, indicating extensive reaction. On the other hand, the recovery of 2-benzylquinoline was high even though a negative Color Test I[2] was obtained. This suggested that the methylene carbon atom was metalated by the phenyllithium. The acid which should have been formed by carbonation of this organometallic compound would undoubtedly be easily decarboxylated with the reformation of the 2-benzylquinoline, which was recovered.

The reaction with 2-allyloxyquinoline and phenyllithium was run to see if any allylbenzene might be formed as in the reaction of "hindered carbonyl compounds" with the Grignard reagent.[3] No allylbenzene was isolated though the low yield of 2-phenylquinoline and poor recovery of starting material showed that reaction other than cleavage had taken place. In view of the fact that 2-allyloxyquinoline does have an α-hydrogen (the 3-position of quinoline is analogous to the α-position of esters) an α-allyl acid[4] might be expected, but no 3-allylcarbostyril (corresponds to α-allyl acid of the aquo system) could be isolated. Similar results were obtained with 2-benzylquinoline.

In Table II are shown the experimental data for reactions with *n*-butyllithium.[5] In general the yields of 2-*n*-butylquinoline were lower than the yields of 2-phenylquinoline. The only important exception was 2-(N-piperidyl)-quinoline which gave a 17.8% yield of 2-*n*-butylquinoline, whereas with phenyllithium it yielded no 2-phenylquinoline. The recovery of starting material was also lower, indicating extensive side reactions. The time required for a negative Color Test I[2] was shorter, even though a lower temperature was employed in some cases. For example, the reaction with 2-chloroquinoline was much improved by running at −45° rather than at 0°. Metalation was a side reaction of 2-ethoxyquinoline as evidenced by the production of 2-ethoxyquinoline-3-carboxylic acid on carbonation.[6]

TABLE II

REACTIONS OF *n*-BUTYLLITHIUM WITH 2-SUBSTITUTED QUINOLINES



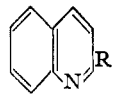
No.	R	Yield of 2-*n*-butylquinoline,[a] %	Yield of cleavage product, %	Reaction time, hr.	*T*, °C.	Recovery of starting material, %
1	$CH_3C_6H_4S$-	13.3	*p*-Thiocresol (11.2)[b]	0.25	−75	82.2[c]
2	$CH_3C_6H_4S$-	63.8	*p*-Thiocresol (35)[b]	0.1	28	...
3	C_6H_5O-[d]	9.6	Phenol (62.6)[e]	4.0	28	14.9[f]
4	C_2H_5O-[g]	49.4	(Ethanol)[h]	0.3	28	14.9[i]
5	Cl-	11.4	.....	.3	0	...
6	Cl-	52.2	.....	.6	−45	...
7	$C_5H_{10}N$-	17.8	.....	4.0	28	...

[a] Identified by the m.p. (163°) of the picrate and a mixed m.p. determination with an authentic specimen. [b] Identified by m.p. (43-45°) and a mixed m.p. determination. [c] Identified by m.p. (68°) and mixed m.p. with an authentic specimen. [d] Friedländer and Ostermaier, *Ber.*, **15**, 332 (1882). [e] Identified by m.p. (41-42°) and a mixed m.p. determination. [f] Identified by m.p. (66°) and mixed m.p. with 2-phenoxyquinoline. [g] Bogert and May, THIS JOURNAL, **31**, 507 (1909). [h] Not isolated. [i] $n^{20}D$ 1.5882.

The reactions with phenylmagnesium bromide are listed in Table III. In these experiments the yields of 2-phenylquinoline were low and the recovery of starting materials was high showing a much lower reactivity. 2-Chloroquinoline, however, showed a particularly high reactivity with the Grignard reagent and formed 2-phenylquinoline in 31.2% yield.[7] Phenylcadmium chloride, an organometallic compound of still lower reactivity, showed no reaction at all with 2-chloroquinoline or 2-ethoxyquinoline under corresponding conditions. As would be expected, the order of reactivity of the various organometallic compounds was: n-C_4H_9Li > C_6H_5Li > C_6H_5MgBr > C_6H_5CdCl.

TABLE III

REACTIONS OF PHENYLMAGNESIUM BROMIDE WITH 2-SUBSTITUTED QUINOLINES



No.	R	Yield of 2-phenylquinoline,[a] %	Yield of cleavage product, %	Reaction time, hr.	*T*, °C.	Recovery of starting material, %
1	$CH_3C_6H_4S$-	3.1	*p*-Thiocresol (4.2)[b]	18	28	74.6[c]
2	C_6H_5O-[d]	2.6	.....	48	28	84.7[e]
3	C_2H_5O-[f]	..	.....	18	28	90.8[g]
4	Cl-	31.2	.....	48	28	50.6[h]
5	$C_5H_{10}N$-	..	.....	60	28	78.8[i]

[a] See footnote *a*, Table I. [b] See footnote *b*, Table I. [c] Identified by m.p. (68°) and mixed m.p. with an authentic specimen. [d] Friedländer and Ostermaier, *Ber.*, **15**, 332 (1882). [e] Identified by mixed m.p. with an authentic specimen. [f] Bogert and May, THIS JOURNAL, **31**, 507 (1909). [g] B.p. 106° at 0.3 mm.; $n^{20}D$ 1.5876. [h] B.p. 115° at 0.03 mm. [i] M.p. 51° after crystallization from petroleum ether (b.p. 60-70°).

The outstanding feature of the chemistry of the reactive organometallic compounds with quinoline compounds is the apparent ease of addition to the azomethine linkage.[8] This reaction with organolithium reagents is smooth and rapid even at low temperature; for example, a 93% yield of 2-*n*-butylquinoline[9] is obtained from *n*-butyllithium and quinoline at −35°, and at −75° the yield is still 84.2%. Phenyllithium adds across the azomethine linkage of 2-arylquinolines to yield 2,2-diaryl-1,2-dihydroquinolines.[10] Phenylmagnesium bromide adds to quinoline in 7% yield if kept at the reflux point of ether for 48 hours.[11]

The 4-halogen was found to be unaffected if the 2-position were open. Thus, 4,7-dichloroquinoline reacted with phenyllithium at 0° to yield 2-phenyl-4,7-dichloroquinoline[12] in 84.9% yield. This compound showed a violent reaction with phenyllithium, but no pure products were isolated from the reaction mixture.

(2) Gilman and Schulze, THIS JOURNAL, **47**, 2002 (1925).
(3) Arnold, Bank and Liggett, *ibid.*, **63**, 3444 (1941); Arnold and Liggett, *ibid.*, **64**, 2875 (1942); *ibid.*, **67**, 337 (1945).
(4) Arnold and Searles, Jr., *ibid.*, **71**, 1150 (1949).
(5) Gilman, Beel, Brannen, Bullock, Dunn and Miller, *ibid.*, **71**, 1499 (1949).
(6) Gilman and Beel, *ibid.*, **73**, 32 (1951).
(7) Hauser and Weiss, *J. Org. Chem.*, **14**, 310 (1949).
(8) Ziegler and Zeiser, *Ann.*, **485**, 174 (1931).
(9) Gilman and Spatz, THIS JOURNAL, **63**, 1553 (1941).
(10) Gilman and Gainer, *ibid.*, **69**, 877 (1947).
(11) Gilman and Gainer, *ibid.*, **71**, 2327 (1949).
(12) Gilman and Benkeser, *ibid.*, **69**, 123 (1947).

The preparation of 2-benzylquinoline which we employed affords this compound in better yield than has been possible previously. By adding benzylsodium, prepared by the metalation of toluene with phenylsodium, to quinoline and oxidizing the dihydro compound with mercuric oxide, a 34% over-all yield of 2-benzylquinoline was obtained. No 2-benzylquinoline was obtained, however, in a reaction between benzylmagnesium chloride and 2-chloroquinoline. Most of the other 2-substituted quinolines used in these experiments were obtained by a metathetical reaction between 2-chloroquinoline and the appropriate lithium or sodium salt.

Experimental

The reactions of the 2-substituted quinolines with the various organometallic compounds were all run in ether under an atmosphere of dry, oxygen-free nitrogen. Many of the reaction mixtures were carbonated by pouring into a slush of ether and Dry Ice; however, no acids were isolated except in the case of 2-ethoxyquinoline and *n*-butyllithium.[6] The more pertinent data on the cleavage reactions are listed in Tables I, II and III.

p-Tolyl 2-Quinolyl Sulfide.[13]—An excess of *p*-thiocresol was dissolved in absolute ethanol and lead acetate was added. The canary-yellow precipitate was filtered and washed with water and then with alcohol before drying in a vacuum desiccator.

A mixture of 11.1 g. (0.025 mole) of dry lead *p*-thiocresoxide and 12.3 g. (0.075 mole) of 2-chloroquinoline was heated to 150° for 5 hours while the mixture turned from yellow to white. After cooling the *p*-tolyl 2-quinolyl sulfide was extracted from the lead chloride with ether. The ether layer was dried over sodium sulfate and the ether removed by distillation. The resultant oil was crystallized from petroleum ether (b.p. 60–70°) to yield 9.4 g. (75%) of *p*-tolyl 2-quinolyl sulfide (m.p. 68°).

Anal. Calcd. for $C_{16}H_{13}NS$: S, 12.76. Found: S, 12.87.

In another preparation 31 g. (0.25 mole) of *p*-thiocresol in 100 ml. of ether was treated with 0.25 mole of phenyllithium in 208 ml. of ether. To the slurry of lithium *p*-thiocresoxide was added 41 g. (0.25 mole) of 2-chloroquinoline and the ether was removed by distillation. The residue was heated to 140° for 18 hours. After cooling, water was added and the organic material extracted with ether. The ether layer was dried over sodium sulfate and the ether removed by distillation. Crystallization of the residue from petroleum ether (b.p. 77–115°) yielded 50.5 g. (80.3%) of *p*-tolyl 2-quinolyl sulfide (m.p. 68°).

2-Allyloxyquinoline.[14]—Into 150 ml. of allyl alcohol was dropped 4.6 g. (0.2 g.-atom) of sodium. After the reaction subsided, 32.7 g. (0.2 mole) of 2-chloroquinoline was added and the mixture refluxed for 18 hours. The excess allyl alcohol was removed by distillation under vacuum and ether and water were added to the residue. The oil from the ether layer was distilled at about 0.05 mm. to yield 32.6 g. (87%) of 2-allyloxyquinoline ($n^{20}D$) 1.5942; d^{20}_4 1.0912. Calcd. for $C_{12}H_{11}NO$: MR_D 57.00. Found: MR_D, 57.61.

2-(N-Piperidyl)-quinoline.—A mixture of 17.0 g. (0.2 mole) piperidine and 33.3 g. (0.2 mole) of 2-chloroquinoline was heated to 130° for 18 hours. The solid reaction mixture was cooled and dissolved in dilute hydrochloric acid and precipitated by the addition of 10% sodium hydroxide. The organic material was extracted with ether and the ether extracts dried over sodium sulfate. After removal of the ether by distillation the residue was recrystallized from petroleum ether (b.p. 60–70°) to yield 32.9 g. (81.6%) of 2-(N-piperidyl)-quinoline (m.p. 41–48°). This product was redissolved in petroleum ether (b.p. 60–70°) and decolorized with carbon. On cooling 24.4 g. (57.6%) of pure 2-(N-piperidyl)-quinoline (m.p. 51°) was obtained.

Anal. Calcd. for $C_{14}H_{16}N_2$: N, 13.18. Found: N, 13.10.

The same compound was obtained by stirring 0.10 mole of lithium piperidide, prepared from phenyllithium and piperidine, and 16.3 g. (0.10 mole) of 2-chloroquinoline in ether for 18 hours while the temperature gradually rose from 0 to 28°. On distillation and recrystallization of the product from petroleum ether (b.p. 60–70°), 7.3 g. (36.2%) of 2-(N-piperidyl)-quinoline was obtained. A recovery of 3.3 g. (21.1%) of 2-chloroquinoline raised the net yield to 45.9%.

Benzylmagnesium Chloride and 2-Chloroquinoline.—A solution of 0.10 mole of benzylmagnesium chloride in 80 ml. of ether was cooled to −8° and 16.3 g. (0.10 mole) of 2-chloroquinoline in 50 ml. of ether was added dropwise during 20 minutes. After stirring for 6 hours a Color Test I[2] was faintly positive. The entire reaction mixture was poured into a slush of ether and Dry Ice. After warming to room temperature hydrolysis was effected by ammonium chloride solution. After separation of the layers acidification of the water layer yielded 5.6 g. (36%) of phenylacetic acid. This indicated that something had interfered with the Color Test I which had been only faintly positive.

In the ether layer a small amount of an impure solid (m.p. 155–160°) was found. Also 8.5 g. (52.1% recovery) of 2-chloroquinoline was obtained, but no 2-benzylquinoline[15] was isolated.

2-Benzylquinoline.—Approximately 0.18 mole of benzylsodium[16] was prepared by the metalation of toluene with phenylsodium. This was cooled to −40° (bath temperature) and 30 ml. of quinoline was added. After stirring for 1 hour a Color Test I[2] was weakly positive, so the reaction mixture was carbonated by pouring into a slush of ether and Dry Ice. After hydrolyzing with water, the layers were separated and the water layer acidified with hydrochloric acid, but no acid was obtained.

The ether layer was dried over sodium sulfate and the ether removed by distillation. The residue was distilled to yield 15 g. of quinoline and 15.4 g. of a yellow oil (b.p. 145–150° at 0.04 mm.). This oil formed a reddish-orange picrate which melted at 153.5–154.5°. Recrystallization from 90% ethanol did not change the melting point.

The yellow oil was dissolved in anhydrous ethanol, and 15 g. of mercuric oxide was added. After heating on a steam-plate for 18 hours, the mercury and mercuric oxide were removed by filtration. The alcohol was removed by distillation and the residue was distilled to yield 13.4 g. (34%) of 2-benzylquinoline (b.p. 145–150° at 0.04 mm.), identified by melting point of the picrate (154–155°) and mixed melting point with an authentic specimen prepared by fractional crystallization of the picrates of 2- and 4-benzylquinoline from *n*-propyl alcohol. The mixture of 2- and 4-benzylquinoline was obtained by treatment of quinoline with benzylmagnesium chloride in dioxane.[15]

Phenyllithium and 2-Chlorobenzothiazole.—To a solution of 10.6 g. (0.06 mole) of 2-chlorobenzothiazole in 50 ml. of ether was added 120 ml. of 0.96 *M* phenyllithium[17] in ether. During the addition a rapid refluxing occurred. The mixture was stirred for eighteen hours before hydrolyzing with 100 ml. of water. The ether was removed by distillation from the ether layer and replaced with 95% ethanol. Cooling this solution yielded 4.6 g. (36.6%) of 2-phenylbenzothiazole (m.p. 106–110°). By recrystallizing from 95% ethanol the melting point was raised to 114°. The identity of the product was confirmed by a mixed melting point with an authentic specimen.[18]

Phenylcadmium Chloride and 2-Chloroquinoline.—To a suspension of 0.10 mole of phenylcadmium chloride[19] in 70 ml. of ether was added a solution of 16.3 g. (0.10 mole) of 2-chloroquinoline in ether. The mixture was stirred at room temperature for 18 hours before hydrolyzing with a solution of ammonium chloride and ammonium hydroxide. The layers were separated; the ether layer was dried over sodium sulfate and the ether removed by distillation. The residue was distilled to yield 15.9 g. (97.5% recovery) of 2-chloroquinoline (b.p. 124° at 0.5 mm.), identified by melting point of the picrate (126–127°) and mixed melting point with an authentic specimen.

Phenylcadmium Chloride and 2-Ethoxyquinoline.—To a suspension of 0.10 mole of phenylcadmium chloride[19] in 120

(13) Brooker and Van Dyke, British Patent 483,071 (May 12, 1938) [*Chem. Zentr.*, **109**, II, 1863 (1938)].

(14) Chichibabin and Jeletsky, *Ber.*, **57**, 1158 (1924); see, particularly, Buu-Hoi, Kiong-Ki-Wei and Royer, *Bull. soc. chim.*, **12**, 866 (1945) [*C. A.*, **40**, 3736 (1946)].

(15) Bergmann and Rosenthal, *J. prakt. Chem.*, [2] **135**, 267 (1932).

(16) Gilman, Pacevitz and Baine, THIS JOURNAL, **62**, 1518 (1940).

(17) Gilman, Zoellner and Selby, *ibid.*, **52**, 1252 (1933).

(18) Bogert and Abrahamson, *ibid.*, **44**, 826 (1922).

(19) Gilman and Nelson, *Rec. trav. chim.*, **55**, 518 (1936).

ml. of ether was added a solution of 17.3 g. (0.10 mole) of 2-ethoxyquinoline in ether. The suspension turned from black to white during the 48-hour stirring time. The mixture was hydrolyzed with a solution of ammonium chloride and ammonium hydroxide. The ether layer was dried over sodium sulfate and the ether removed by distillation. The residue was distilled to yield 16.1 g. (93.2% recovery) of 2-ethoxyquinoline (b.p. 81–83° at 0.05 mm.).

Phenyllithium and 4,7-Dichloroquinoline.—A solution of 0.10 mole of phenyllithium in 100 ml. of ether was added dropwise at 0° to 19.8 g. (0.10 mole) of 4,7-dichloroquinoline in 300 ml. of ether. After stirring for 1 hour a yellow precipitate had formed and a Color Test I was negative. After hydrolysis with water the layers were separated and the ether layer dried over sodium sulfate. The ether was replaced with 400 ml. of anhydrous ethanol and 30 g. of mercuric oxide was added. After keeping this mixture just below the boiling point for 18 hours the mercury and mercuric oxide were removed by filtration. On cooling this solution yielded 19.6 g. of product (m.p. 100.5–101.5°). Concentration of mother liquors yielded 4.3 g., or a total of 23.2 g. (84.9%) of 2-phenyl-4,7-dichloroquinoline.[12] Recrystallized from ethanol the compound melted at 101–102°.

Phenyllithium and 2-Phenyl-4,7-dichloroquinoline.—A solution of 0.05 mole of phenyllithium[17] was added to a suspension of 13.7 g. (0.05 mole) of 2-phenyl-4,7-dichloroquinoline in 200 ml. of ether at 0° (bath temperature). The mixture turned black and gave no Color Test I[2] at the end of 1 hour. The suspension was poured into a slush of ether and Dry Ice and after warming to room temperature was hydrolyzed with 100 ml. of water. This was a mixture of substances which resisted all attempts at separation by fractional crystallization.

The reaction was repeated between −50° and room temperature for 12 hours, and a precipitate was obtained after hydrolysis. Chromatographic adsorption effected some separation but the small amounts of material obtained were not pure enough to analyze.

Summary

1. 2-Electronegatively substituted quinolines have been cleaved by *n*-butyllithium, phenyllithium and phenylmagnesium bromide to form 2-aryl- or alkylquinolines.

2. Of these three organometallic compounds phenyllithium gives the highest yields of cleavage products. Because it is more reactive, *n*-butyllithium causes more extensive side reactions. Phenylcadmium chloride does not effect the cleavage reaction.

3. The electronegative groups which have been cleaved from the 2-position of quinoline are Cl–, $CH_3C_6H_4S$–, C_6H_5O–, C_2H_5O–, C_3H_5O–, C_6H_5–CH_2O– and $C_5H_{10}N$–.

AMES, IOWA RECEIVED JUNE 26, 1950

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF THE UNIVERSITY OF CALIFORNIA]

Allylic Rearrangements. XXIX. Relative Tendencies of Nucleophilic Substitution in Organic Halides

BY IRVING D. WEBB[1] AND WILLIAM G. YOUNG

In the dual mechanism hypothesis of nucleophilic substitution at a saturated carbon atom[2,3] the tendencies of various alkyl halides to undergo the S_N2 reaction decrease in the order methyl, ethyl, isopropyl, *t*-butyl, while the tendencies to undergo the S_N1 reaction increase in the same order. Frequently reaction conditions are such that both mechanisms take place in a given substitution reaction, notably so with isopropyl halides. It is generally believed that in an S_N2 reaction the nucleophilic agent attacks the tetrahedral carbon atom opposite the position from which a group is leaving. The decrease in S_N2 tendency in the series methyl to *t*-butyl has been attributed to an increase in steric hindrance to "back-side" attack on carbon by the nucleophile.[4] The decrease in reactivity to S_N2 in this series has also been attributed partially to a decrease in the attraction of carbon substituted with alkyl groups for the nucleophilic agent, due to electron release by the alkyl groups.[2,5]

However, this latter hypothesis appears not to be general. After completion of the present work[1] in 1944, Evans[4c] reached the same conclusion by considering the evidence of Hughes[6] and of Young and Andrews.[7] There followed an exchange of publications[8] concerned with the relative importance of polar effects and steric effects in substitution reactions. If we interpret Hughes and Ingold[8a] correctly, they would expect a retarding effect on alkyl groups on the rate (bimolecular) of reaction of alkyl halides with halide or ethoxide ions in ethanol. However, they have pointed out that exceptions to the stated effect on the bimolecular mechanism sometimes arise in the neighborhood of the bimolecular–unimolecular transition region.[9]

In the case of allylic systems[1] the effect of alkyl groups is clearly one of acceleration. Thus an increase in the rate of bimolecular substitution with an increase in electron accession at the seat of substitution is clearly demonstrated by the marked increases in second order rate constants as the hydrogens in the gamma position of allylic halides are replaced with alkyl groups. With these gamma-substituted allylic halides steric

(1) The contents of this paper were taken from a thesis presented by Irving D. Webb for the degree of Ph.D., June 24, 1944.

(2) Hughes, *J. Chem. Soc.*, 968 (1946).

(3) Roberts, Young and Winstein, THIS JOURNAL, **64**, 2157 (1942).

(4) (a) Bergmann, Polanyi and Szabo, *Z. physik. Chem.*, **20B**, 162 (1933); (b) Bartlett and Rosen, THIS JOURNAL, **64**, 543 (1942); (c) Evans, *Nature*, **157**, 438 (1946).

(5) (a) Hughes and Ingold, *J. Chem. Soc.*, 244 (1935); (b) Catchpole, Hughes and Ingold, *ibid.*, 15 (1948).

(6) Hughes, *Trans. Faraday Soc.*, **37**, 603 (1941).

(7) Young and Andrews, THIS JOURNAL, **66**, 421 (1944).

(8) (a) Hughes and Ingold, *Nature*, **158**, 94 (1946); (b) Evans, *Trans. Faraday Soc.*, **42**, 719 (1946); (c) Evans, "The Reactions of Organic Halides in Solutions," Manchester University Press, 1940; (d) Evans, *Nature*, **158**, 586 (1946); (e) Evans, *ibid.*, **159**, 166 (1947); (f) Evans, *J. Chem. Soc.*, 558 (1947); (g) Hughes and Ingold, *Nature*, **159**, 166 (1947); (h) Dostrovsky, Hughes and Ingold, *J. Chem. Soc.*, 1283 (1948).

(9) (a) Hughes, *Trans. Faraday Soc.*, **37**, 609 (1941); (b) Hughes, Ingold and Shapiro, *J. Chem. Soc.*, 228 (1936).