hydrobromide as a catalyst. Thus the "siliconium ion" or an intermediate ethoxyiodosilane might undergo rapid intermolecular elimination of ethyl iodide.

Experimental

All the reactions described were run under essentially the same experimental conditions and are illustrated by the following experiment with allyldiethoxyphenylsilane.

Allyldiethoxyphenylsilane (101.6 g./0.430 mole) was cooled in an ice–water-bath. A total of 116.5 g. of iodine (0.459 mole) was added in small portions over a 260-minute period with vigorous stirring. The cold mixture was stirred for an additional 1.5 hours and then quickly transferred to a claisen flask already equipped for vacuum distillation. The pressure was reduced rapidly and 58.1 g. (I) of product was collected over a one-hour period in a trap immersed in a Dry Ice–trichloroethylene-bath. The pressure in the system was 6 mm. and the temperature of the residue was −6°. The distillation was discontinued and the flask was allowed to warm to room temperature. Reapplying a vacuum of 5 mm. gave an additional 70.6 g. (II) of product, heat being applied to keep the temperature from falling. A dark viscous oil remained in the claisen flask; gross yield 128.7 g. (92.4%) of distillate.

Fraction I was distilled in a 2-ft. Podbielniak Minical column to yield 19.25 ml. of ethyl iodide, b.p. 71.1–72.2° (742 mm.), and 6.85 ml. of allyl iodide, b.p. 102.5–102.9° (742 mm.). Fraction II, combined with the column hold-up of fraction I was distilled in the same column and an additional 11.65 ml. of ethyl iodide and 19.4 ml. of allyl iodide was obtained; total yield ethyl iodide 88.3%, allyl iodide 66.9%. An intermediate fraction, 2.30 ml., was discarded. Ethyl iodide was characterized by its physical constants, $n^{25}D$ 1.5062–1.5089, lit. $n^{25}D$ 1.5076,[7] lit. b.p. 72.2–72.4°,[7] and as the anilide, m.p. 103.5–104°, lit. m.p. 104°.[8] Allyl iodide was characterized by its physical constants d^{25}_4 1.837, lit.[9] d^{22}_4 1.8454, b.p. 101–102°.

(7) S. W. Prentiss, THIS JOURNAL, **51**, 2830 (1929).
(8) H. W. Underwood and J. C. Gale, *ibid.*, **56**, 2119 (1934).
(9) R. L. Letsinger and J. G. Traynham, *ibid.*, **70**, 2818 (1948).

WESTINGHOUSE RESEARCH LABORATORIES
PITTSBURGH 35, PENNSYLVANIA

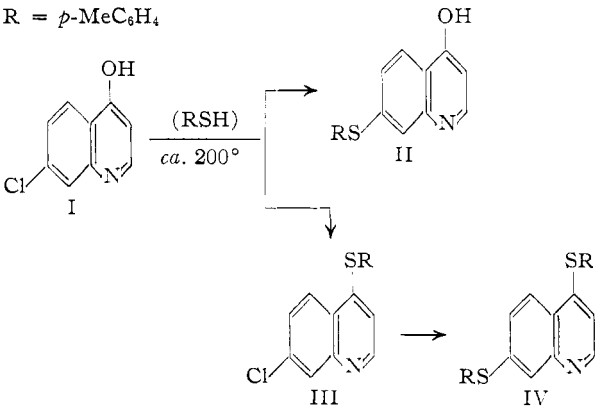
4-Hydroxyquinolines. Effect of a 7-Substituent on the Displaceability of the Hydroxyl Group[1]

BY GABRIELLO ILLUMINATI AND LUDOVICO SANTUCCI

RECEIVED AUGUST 8, 1955

As shown in a previous paper,[2] the hydroxyl group can be displaced from 4-hydroxy-7-chloroquinoline (I) by the action of *p*-thiocresol in the fused state. The reaction yielded two substitution products, 4-hydroxy-7-*p*-tolylmercaptoquinoline (II) and 4,7-di-(*p*-tolylmercapto)-quinoline (IV). Since the displacement of a hydroxyl group with common nucleophilic reagents is rare in aromatic substitutions, it seemed of interest to investigate the course of this reaction in more detail.

We have found that compound II is not an intermediate in the reaction leading to compound IV; under identical experimental conditions it did not react with the thiol and could be recovered practically unchanged. The structure of compound II, which had been previously established,[2] was confirmed by additional evidence. By treatment with phosphorus oxychloride such a compound was converted to the expected 4-chloro-7-*p*-tolylmercaptoquinoline which, in turn, reacted with *p*-thiocresol to give compound IV. Compound IV is therefore formed from compound I by an independent process involving the primary displacement of the hydroxyl group and the consequent formation of 4-*p*-tolylmercapto-7-chloroquinoline (III) as the intermediate. This is shown by the fact that under the same experimental conditions compound III is converted to the dimercapto derivative IV.[3] Also, starting from compound I, in addition to products II and IV, we have detected small amounts of the intermediate compound III. The course of the total reaction is therefore as illustrated in the scheme



Based on the minimum yield (22%) of pure 4,7-di-(*p*-tolylmercapto)-quinoline, m.p. 100.5–101.5°, as deduced from several experiments, the extent of displacement of the hydroxyl group from compound I was found to be of the same order as that of the 7-chlorine atom from the same compound. Side-reaction products were isolated in the course of the product analysis as described in the Experimental part.

The main interest of our results is that they show the dependence of the ability of the hydroxyl group to be displaced on the nature of the far-removed substituent in the 7-position of the quinoline ring. Under the conditions of our experiments, the chlorine atom in this position allows the displacement of the hydroxyl group from the 4-position whereas the *p*-tolylmercapto group does not. Provided that compounds I and II react in the 4-hydroxyl form, their apparent relative reactivity is clearly consistent with the electronic effects of chlorine and of the *p*-tolylmercapto group in the 7-position. Basicity studies[4] show that chlorine in monochloroquinolines exerts an appreciably strong -I inductive effect[5] from the benzenoid ring to the nitrogen atom. The order of basicity constants as found by us[6] in a 4-chloroquinoline series is as follows: 7-*p*-tolylmercapto > 7-Cl, from which a reverse order of reactivity in nucleophilic substitutions would be expected. Kinetic studies in this Laboratory[6] on displacement of chlorine from the 4-position with eth-

(1) Part IV in the series "Nucleophilic Displacements by Thiols." Part III: G. Illuminati and L. Santucci, *Gazz. chim. ital.*, **83**, 1106 (1953).
(2) G. Illuminati and H. Gilman, THIS JOURNAL, **72**, 4288 (1950).
(3) See Part III, ref. 1.
(4) S. B. Knight, R. H. Wallick and C. Balch, THIS JOURNAL, **77**, 2577 (1955).
(5) For the sign of the symbols used in this work see, for example, the appendix in J. W. Baker, "Hyperconjugation," Oxford at the Clarendon Press, 1952.
(6) Unpublished studies.

TABLE I

PRODUCT ANALYSIS FOR THE REACTIONS OF 4-HYDROXY-7-CHLOROQUINOLINE (I) AND OF 4-HYDROXY-7-*p*-TOLYLMERCAPTOQUINOLINE (II) WITH *p*-THIOCRESOL AT ABOUT 200°[a]

Expt.	Hydroxyquinoline, g.	Moles of thiol/mole of hydroxyquinoline	Reaction time, hr.	Alkaline fraction (crude I) G.	M.p., °C.	Yield, %	Ether fraction: Crude base from the sulfate mixture G.	M.p., °C.	Pure 4,7-di-*p*-tolylmercapto derivative (IV) G.	M.p., °C.	Yield, %
1	I (1.20)	6	6	0.70	229–236	39.0	0.88	93–96	0.65	100–101	25.1
2	I (19.41)	3	10.5	10.88	233–239	37.4	14.33	66–94	8.78	100–101	21.8
3	II (0.52) m.p. 243.5–245°	6	6	0.51	237–240	98.0 (recovery)	0.06	not recorded	..	.....	..

[a] All known products were identified, after purification, by mixed m.p.'s with corresponding authentic samples. The purity of compound IV was given an additional check by sulfur analysis.

oxide ion confirm the expectations, since 4,7-dichloroquinoline reacts faster than 4-chloro-7-*p*-tolylmercaptoquinoline, thus displaying the same order of reactivity of the corresponding 4-hydroxy compounds as illustrated in the present work. The relative importance of +T tautomeric effects from the 7-position to the position of attack may also have a role in determining relative reactivities because, although the direct operation of the tautomeric effect from the 7-position to the 4-position is absent, such effects give a direct contribution to the nitrogen atom, thus reducing the activating ability of the latter.

Despite the above-mentioned experimental evidence, the reactivity order observed for compounds I and II may also result from the contribution of other factors. Firstly, depending on the nature of the substituents, conjugation of the hydroxyl group with the ring may be supposed to influence its own displaceability; however, this is still a questionable matter[7] and we do not know to what an extent conjugation affects relative rates. Secondly, the importance of double bondness in the C–O bond would become predominant should part of the molecules of the hydroxyquinoline react in the keto form, although the extent to which the 4-hydroxyl form is in equilibrium with the 4-keto form is probably small under the conditions of the experiments herein described.

Experimental

Comparative Experiments with 4-Hydroxy-7-chloro- (I) and 4-Hydroxy-7-*p*-tolylmercaptoquinoline (II). General Procedure for the Product Analysis.—A well-ground mixture of *p*-thiocresol and the 4-hydroxyquinoline compound in a molar ratio varying from 3:1 to 6:1 was allowed to react for 1 to 14 hours at approximately constant temperature. The experiments were carried out in the ground-glass stoppered vessel of a Pyrex boiling-vapor thermostat surrounded in the external jacket by the boiling glycol vapor (197°). If a molar sixfold excess of the thiol was used, in order to allow the reaction mixture to reach the equilibrium temperature it was found desirable to place it in a constricted Pyrex tube and to immerse the tube, after sealing, in the vessel filled with glycerol as a liquid bath. In all cases an homogeneous liquid resulted during the immersion. After a fixed time, the reaction mixture was cooled off and vigorously shaken with a 10% sodium hydroxide solution and diethyl ether. The sealed tubes were first crushed under the sodium hydroxide solution in a heavy glass bottle and, then, the resulting mixture treated with diethyl ether. The two immiscible solutions thus formed were separated and examined separately

(a) **Alkaline Fraction.**—As this would contain any 4-hydroxyquinoline derivative and the unreacted thiol, it was treated with petroleum ether and acidified with 10% hydrochloric acid under vigorous shaking. By such a treatment the unreacted thiol set free on acidification dissolved in the petroleum ether layer while the insoluble 4-hydroxyquinoline which separated was isolated by filtration. This product was washed with several portions of petroleum ether and then with a dilute acetic acid solution and finally dried. In the reaction of 4-hydroxy-7-chloroquinoline for six hours or more (Table I, expts. 1 and 2), the solid was found to consist of a crude 4-hydroxy-7-*p*-tolylmercaptoquinoline usually melting in the range 230–240°. In agreement with previously reported results,[2] the crude product was purified by recrystallization from 95% ethanol to give samples in about 26% yields melting at 243.5–245°. However, one sample (expt. 2) of crude product, m.p. 233–239°, was directly used with good results for the preparation of 4-chloro-7-*p*-tolylmercaptoquinoline (see below).

In the attempted reaction of 4-hydroxy-7-*p*-tolylmercaptoquinoline (Table I, expt. 3), m.p. 243.5–245°, the alkaline fraction was found to contain practically the whole starting material with a slightly lowered melting point (about 240°).

(b) **Ether Fraction.**—This fraction would contain any product of displacement of the hydroxyl group and any other non-acidic side-reaction product. After distillation of the solvent, the resulting solid residue was intimately mixed with a 20% sulfuric acid solution by grinding in a mortar. In this manner all basic material was converted into a yellow sulfate mixture which, after removal of the aqueous acidic liquor by filtration, was again ground in a mortar and thoroughly mixed with several portions of petroleum ether. The combined petroleum ether liquors were always found to contain some *p*-tolyl disulfide which could be isolated in the form of pale-colored crystals melting in the range 42–44°. The yellow sulfate mixture, by treatment with a 5% sodium hydroxide solution and diethyl ether, was converted back to a crude base, which was recovered from the ether layer after removal of the solvent. In the reaction of 4-hydroxy-7-chloroquinoline (expts. 1 and 2), the crude base was found to be impure 4,7-di-(*p*-tolylmercapto)-quinoline melting over a range of several degrees, from which the main contaminating material was removed by extraction with petroleum ether. After this extraction, the residue was the nearly pure product and on recrystallization from 95% ethanol it melted at 100.5–101.5°. The contaminating material, which was recovered from the combined petroleum ether extracts, was a basic oil which remained unidentified. In some cases, before treatment with petroleum ether, isolated crystals of 4-*p*-tolylmercapto-7-chloroquinoline (III), m.p. 135–136°, were mechanically separated from the crude base.

In the attempted reaction of 4-hydroxy-7-*p*-tolylmercaptoquinoline (expt. 3), only very small amounts of crude base were obtained which were not worked up any further.

Experiments 1, 2 and 3 are examples out of sets of several runs which essentially confirmed each other. In particular, in all attempted reactions with 4-hydroxy-7-*p*-tolylmercaptoquinoline, the starting material was recovered even after 14 hours in a form of varying purity from which the pure compound could be obtained by one recrystallization from ethanol. Also, in the reaction with 4-hydroxy-7-chloroquinoline, the yields reported in Table I (expts. 1 and 2) for compound IV can be considered as the minimum extent of displacement of the hydroxyl group as found in all experiments lasting six hours or more. We found that such yields fluctuate in rather a large range and, in some cases, can be as high as 44%; although this may be due to the manner in which heating is initially applied, we have not tried to ascertain the cause for the fluctuation. The starting 4-hydroxy-7-chloroquinoline could only be isolated from experiments run for less than six hours.

(7) J. F. Bunnett and R. E. Zahler, *Chem. Revs.*, **49**, 273 (1951).

4-Chloro-7-*p*-tolylmercaptoquinoline.—A solution of 10.88 g. of 4-hydroxy-7-*p*-tolylmercaptoquinoline (0.041 mole), m.p. 233–239° (expt. 2), was gently refluxed with 41 ml. of phosphorus oxychloride for two hours. Then the excess of oxychloride was removed by distillation at reduced pressure (20 mm.) and the residue was treated with cold dilute ammonia and extracted with ether. On removal of the solvent, 10.30 g. of a crude, tan-colored product was obtained, m.p. 54–57°. For the purification, it was dissolved in 150 ml. of dry petroleum ether (b.p. 30–50°) and filtered from any undissolved material. The solution was applied on an alumina column (18 × 150 mm.) which was eluted with another 350 ml. of the same solvent. From the evaporation of the combined petroleum ether fractions (500 ml.), a residue of 9.74 g. of a white solid, m.p. 58.5–60°, was obtained (83.8%). On recrystallization from petroleum ether (b.p. 52–63°), the melting point was raised to 59.5–60°.

Anal. Calcd. for $C_{16}H_{12}ClNS$: S, 11.22. Found: S, 11.48.

On continuing elution with chloroform, 0.61 g. of a brown-colored, impure residue was obtained after removing the solvent from the eluate. Previous examples of this efficient purification of chloroquinolines by adsorption can be found in the literature.[8]

As a proof of structure, a sample of the 4-chloro-7-*p*-tolylmercaptoquinoline thus obtained was allowed to react with *p*-thiocresol in toluene solution with a concentration about one tenth molar in both reactants. The solution was kept at 80° for a day or so and yellow crystals, m.p. 182.5–191°, separated on cooling. This product was shown to be the hydrochloride of the 4,7-di-(*p*-tolylmercapto) derivative (IV) since by treatment with sodium hydroxide solution, extraction with ether and removal of the solvent, pure crystals of compound IV, m.p. 100.5–101.5°, were obtained.

Acknowledgments.—A preliminary attempt of reaction between compound II and the thiol was run by one of us (G. I.) in Prof. Gilman's Laboratory. The authors are grateful to Profs. V. Caglioti and H. Gilman for helpful discussion. Thanks are also due to Dr. G. Bonola for the duplication of some of the experiments.

(8) B. Riegel, G. R. Lappin and B. H. Adelson, THIS JOURNAL, **68**, 1264 (1946).

DEPARTMENT OF GENERAL CHEMISTRY
UNIVERSITY OF ROME
AND CENTRO DI CHIMICA GENERALE
NATIONAL RESEARCH COUNCIL
ROME, ITALY

Neopentyl Iodide

BY NATHAN KORNBLUM AND DON C. IFFLAND[1]

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Although the synthesis of neopentyl iodide from neopentane by Whitmore, Wittle and Harriman[2] provides this compound in a high state of purity it is time consuming and not well adapted to the synthesis of even moderate amounts (100–200 g.) of the iodide. In contrast, the method recently reported by Landauer and Rydon,[3] by which neopentyl iodide is obtained in 74% yield when neopentyl alcohol is treated with a mixture of methyl iodide and triphenyl phosphite, seems well suited to the preparation of substantial quantities of the iodide.[4]

(1) This research was supported by the United States Air Force under Contract No. AF 18 (600)-310 monitored by the Office of Scientific Research, Air Research and Development Command.

(2) F. C. Whitmore, E. L. Wittle and B. R. Harriman, THIS JOURNAL, **61**, 1585 (1939).

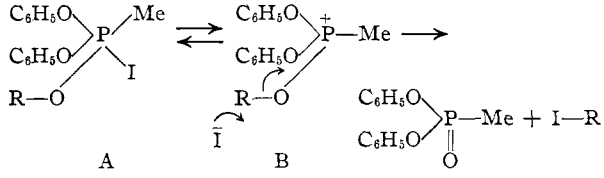
(3) S. R. Landauer and H. N. Rydon, *J. Chem. Soc.*, 2224 (1953).

(4) Whitmore, Wittle and Harriman (ref. 2) found that the reaction of neopentyl alcohol with phosphorus and iodine gives only a 4–9% yield of neopentyl iodide.

It has now been found, however, that although the yield and properties of the product described by Landauer and Rydon may be duplicated routinely, the product is not pure neopentyl iodide but is contaminated with *ca.* 6% of *t*-amyl iodide.

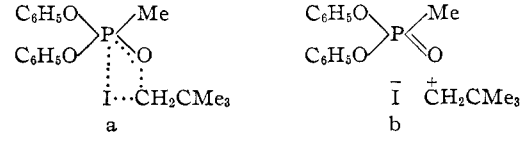
This note describes a modification of the Landauer and Rydon procedure which gives pure neopentyl iodide in 53–57% yield. Direct infrared comparison, using the matched-cell technique, shows that the product is identical with that obtained according to Whitmore, Wittle and Harriman.[2] The present procedure, therefore, constitutes the most convenient method of preparing neopentyl iodide in a high state of purity.

While recognizing that the available evidence is not sufficient to enable a definite conclusion to be reached regarding the mechanism of the reaction of triphenyl phosphite methiodide with alcohols, Landauer and Rydon suggest an SN2 mechanism:



The evidence cited by them[3] for reactions employing primary and secondary alcohols supports this view. But the suggestion that neopentyl iodide is formed by the SN2 mechanism leans heavily on the claim that rearrangement does not occur and, in light of the present finding, loses much of its force.

Actually, we incline to the view that neopentyl iodide is formed by a "frontal attack" which can be envisioned in several ways. In one, the covalent form (A) undergoes "*cis* elimination" thus giving rise to a cyclic transition state (a). Alternatively, the ionic form (B) breaks up to give an ion pair (b) which collapses to neopentyl iodide before rearrangement occurs. (The iodide ion is suitably



located because of the equilibrium between the covalent form (A) and the ionic form (B) and also because of the electrostatic attraction of the positively charged phosphorus for the iodide ion). When combination of the ions is delayed rearrangement occurs and *t*-amyl iodide is formed.[5]

Acknowledgment.—Our thanks are due to Dr. J. W. Amy of this Department for determining the infrared spectra and for assisting us in their interpretation.

Experimental

Neopentyl alcohol was obtained in 85–90% yield by reducing trimethylacetic acid with lithium aluminum hydride: b.p. 110–111°, m.p. 55–56°. Eastman Kodak Co. triphenyl phosphite was used directly. Neopentyl iodide, prepared for reference, according to Whitmore, *et al.*[2], had b.p. 70° (100 mm.), $n^{20}D$ 1.4887. *t*-Amyl iodide from *t*-amyl alcohol and 58% hydriodic acid had b.p. 53° (50 mm.), $n^{20}D$, 1.4976–1.4980.

(5) The material balance has never exceeded 80% and the deficiency may well be due to olefin formation.