information available to us, and for valuable suggestions. We wish also to thank Dr. Horst Adolph for determining the integrated intensities and to acknowledge helpful discussions with Drs. D. V. Sickman, J. C. Dacons, and L. A. Kaplan.

Silver Spring, Md.

[Contribution from the Department of Chemistry of The University of Michigan]

Dihydroquinolines. I. The Action of Metal Hydrides on Quaternary Quinolinium Salts[1]

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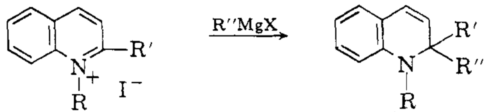
Received September 1, 1961

Reduction of a series of quinolinium salts with lithium aluminum hydride and sodium borohydride results in the formation of mixtures of dihydro- and tetrahydroquinolines. The relative proportions of the products formed is affected by the solvent, the temperature at which the reduction is performed and by the nature of the anion of the quinolinium salt.

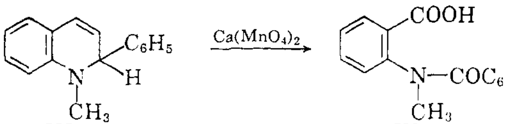
Monomeric 1,2-dihydroquinolines were first synthesized by Freund and Richard[3,4] by the reaction of Grignard reagents on quaternary quinolinium salts (I–II),



I II

R = alkyl; R′ = H, or alkyl; R″ = alkyl or aryl

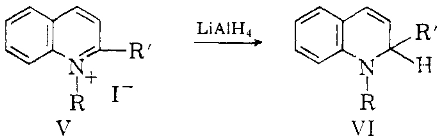
Evidence for assignment of the 1,2-dihydroquinoline structure was based chiefly on the formation of *N*-benzoyl-*N*-methylanthranilic acid (IV) when the product (III) of the reaction of quinoline methiodide with phenylmagnesium bromide was oxidized with calcium permanganate.



III IV

The chemistry of these substances has been studied further by Meisenheimer and co-workers.[5,6] As will be presented in a subsequent communication, choice of III for definitive proof of structure of the products of the Freund reaction as a group was somewhat unfortunate.

In 1949 Schmid and Karrer[7] described the formation of 1,2-dihydroquinoline derivatives by reduction of 1-alkyl-2-substituted quinolinium iodides with lithium aluminum hydride (V–VI),



V VI

R = alkyl; R′ = H, alkyl or aryl

They expressed doubt concerning the validity of the structure assignments for Freund's dihydroquinolines. It was noted that the dihydroquinolines produced by lithium aluminum hydride reduction rapidly lost their reducing power when exposed briefly to strong acid and it was suggested that, inasmuch as Freund had used hydrochloric acid during the work-up of his reaction mixtures, some change may have been effected on the initial products of the reactions. Further, the properties reported by Schmid and Karrer for their compounds were stated to differ somewhat from those of the dihydroquinolines made by the Freund reaction.

In connection with work presently under way in these laboratories, procurement of 1,2-dihydroquinolines of unequivocal structure was necessary. Therefore, in view of the contradictory statements appearing in the literature, an exhaustive study of these interesting and relatively unstable substances was undertaken. The present communication deals with dihydroquinolines prepared by metal hydride reduction of quaternary quinolinium salts. Results of a study of the Freund reaction will be presented in a subsequent communication.

At the outset 1-methylquinolinium iodide (VII) was subjected to the Freund reaction with phenylmagnesium bromide and 2-phenylquinoline methiodide (VIII) was reduced with lithium aluminum hydride in ether. Use of strong mineral acids was avoided in the manipulation of the products of both reactions. If 1,2-dihydroquinolines are indeed formed in the Freund reaction, then the same

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(1) The material presented is taken from a dissertation submitted by Bruce H. Wark in partial fulfillment of the requirements for the Ph.D. degree, University of Michigan.

(2) Visking Division of Union Carbide Corp. Fellow, 1958.

(3) M. Freund, *Ber.*, **37**, 4666 (1904).

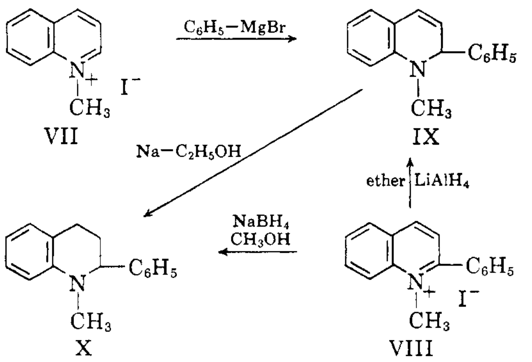
(4) M. Freund and L. Richard, *Ber.*, **42**, 1101 (1909).

(5) J. Meisenheimer and M. Schutze, *Ber.*, **56**, 1353 (1923).

(6) J. Meisenheimer, E. Stotz, and K. Bauer, *Ber.*, **58**, 2826 (1925).

(7) H. Schmid and P. Karrer, *Helv. Chim. Acta*, **32** 960 (1949).

product (IX) should result from either VII or VIII.

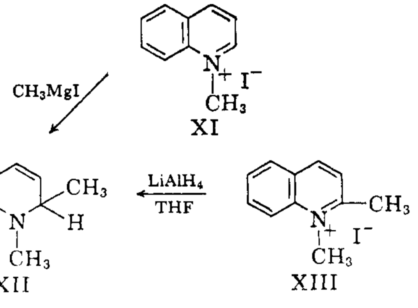


From each of these reactions a white crystalline compound furnishing analytical data demanded by IX was obtained. The two substances were identical on the basis of infrared and ultraviolet spectra. Since VIII possessed a phenyl group in the 2- position it seems reasonable that the product of the Freund reaction on VII also carries a phenyl group in the 2- position. The possibility that IX is a 1,4-dihydroquinoline seems excluded on the basis of the improbability of a shift of the double bond in IX to the 2,3- position.

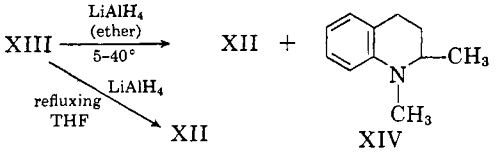
However, when VIII was reduced with sodium borohydride in methanol, again a white crystalline solid which was not identical with IX was obtained. This proved to be 1-methyl-2-phenyl-1,2,3,4-tetrahydroquinoline (X) which was also prepared by reduction of IX with sodium and ethanol. Closer examination of the crude product of the borohydride reduction by quantitative ultraviolet spectroscopy showed it to consist of a mixture of IX, X and a small amount of an oil. After removal of the oil the mixture consisted of 84 mole per cent of IX and 16 mole per cent of X.

Closer examination of the crude product of the lithium aluminum hydride reduction of VIII also showed the presence of X. In contrast to the mixture obtained by borohydride reduction, this consisted of 91 mole per cent of IX and 9 mole per cent of X.

In another series of experiments it was found that the product of the reaction of 1-methylquinolinium iodide (XI) with methylmagnesium iodide, 1,2-dimethyl-1,2-dihydroquinoline (XII), was identical with the product of the reduction of 2-methylquinolinium methiodide (XIII) with lithium aluminum hydride in refluxing tetrahydrofuran.



In contrast, when XIII was reduced with lithium aluminum hydride in ether the ultraviolet spectrum of the product differed significantly from that of pure XII. Reaction of the product with methyl iodide gave a methiodide which, after purification, was identical with the methiodide of 1,2-dimethyl-1,2,3,4-tetrahydroquinoline (XIV), an authentic sample of which was prepared by reduction of XII with sodium and ethanol. Ultraviolet spectrographic analysis of the product of the lithium aluminum hydride reduction of XIII in ether showed the presence of from 7 to 13 mole per cent of XIV depending on conditions (Table I).



Since the relative proportions of dihydro- and tetrahydroquinolines formed in these reductions was influenced not only by the solvent but also by the hydride used, it was of interest to examine the effect, if any, of variation of the anion of the quinolinium salt on the proportions of the products formed. Surprisingly the nature of the anion did exert an effect on the composition of the mixtures of the products of the reaction. These data, obtained by ultraviolet spectrographic analyses, are summarized in Table I.

When the reduction of 1,2-dimethylquinolinium chloride, bromide, iodide or bisulfate with lithium aluminum hydride was carried out in refluxing tetrahydrofuran the mole per cent of tetrahydro compound found in the binary mixture of di- and tetrahydroquinolines varied from zero for the iodide to 25 for the bisulfate with intermediate values for the chloride and bromide. In refluxing ether the mole per cent of tetrahydro compound formed varied from 13 for the iodide to 36 for the bisulfate. It is interesting to note that when 1,2-dimethylquinolinium bisulfate was treated with lithium aluminum hydride at 5–10° no reaction occurred. Under approximately the same conditions the iodide, bromide and chloride gave yields of reduced products ranging from 43 to 87 per cent and the mole percentages of tetrahydro compound in the binary mixtures were 8, 23, and 19, respectively.

Further examination of the data of Table I indicates that factors other than the nature of the anion influence the composition of the mixtures resulting from lithium aluminum hydride reduction of 1,2-dimethylquinolinium salts. When the reduction was done in refluxing ether a higher mole per cent of XII in the binary mixture was obtained than was the case when the temperature

TABLE I

COMPLEX METAL HYDRIDE REDUCTIONS OF 1-METHYL-2-SUBSTITUTED QUINOLINIUM SALTS

Compound Reduced	Reducing Agent[a]	Solvent	Reaction Temp.	Yield, %[b]	Composition[c] of Product
1,2-Dimethylquinolinium iodide	$LiAlH_4$	Ether	5–10°[d]	87%	93:7
"	$LiAlH_4$	Ether	5–10°[e]	43	91:9
"	$LiAlH_4$[f]	Ether	5–10°[e]	62	98:2
"	$LiAlH_4$	Ether	35–40°[g]	76	87:13
"	$LiAlH_4$	THF	70–75°[h]	42	all dihydro
"	$LiAlH_4$[f]	THF	70–75°[i]	57	" "
"	$NaBH_4$[j]	Methanol	5–10°[k]	61	86:14
1,2-Dimethylquinolinium chloride	$LiAlH_4$	Ether	5–10°[l]	61	81:19
"	$LiAlH_4$	Ether	35–40°[m]	35	76:24
"	$LiAlH_4$	THF	70–75°[h]	61	81:19
1,2-Dimethylquinolinium bromide	$LiAlH_4$	Ether	5–10°[n]	66	77:23
"	$LiAlH_4$	Ether	35–40°[m]	69	64:36
"	$LiAlH_4$	THF	70–75°[o]	69	95:5
1,2-Dimethylquinolinium bisulfate	$LiAlH_4$	Ether	5–10[l]	nil	No Reaction
"	$LiAlH_4$	Ether	35–40°[p]	34	64:36
"	$LiAlH_4$	Ether	35–40°[q]	54	62:38
"	$LiAlH_4$	THF	70–75°[h]	35	75–25
1-Methyl-2-phenylquinolinium iodide	$LiAlH_4$	Ether	35–40°[m]	73	91:9
"	$NaBH_4$[j]	Methanol	5–10°[k]	48	16:84

[a] Molar ratio of reducing agent to quinolinium salt was 1:1 unless otherwise noted. [b] Per cent of theoretical based upon moles of quinolinium salt charged. [c] Molar ratio dihydro to tetrahydro compound. [d] Stirred at room temperature for 30 min. [e] Stirred at 5–10° for 60 min. [f] Molar ratio of lithium aluminum hydride to quinolinium salt was 2:1. [g] Refluxed in ether for 12 hr. [h] Refluxed in tetrahydrofuran for 19 hr. [i] Refluxed in tetrahydrofuran for 32 hr. [j] Molar ratio of sodium borohydride to quinolinium salt was 4:1. [k] Stirred at room temperature for 24 hr. [l] Stirred at 5–10° for 3 hr. [m] Refluxed in ether for 45 hr. [n] Stirred at room temperature for 90 min. [o] Refluxed in tetrahydrofuran for 42 hr. [p] Refluxed in ether for 4 hr. [q] Refluxed in ether for 72 hr.

was 5–10° regardless of the nature of the anion. However, no such correlation between reaction temperature and total yield of products was observed.

On the other hand, a lower mole per cent of tetrahydro compound was invariably found in the binary mixture of products when the reductions were carried out in refluxing tetrahydrofuran rather than ether. The higher reaction temperature obtained with tetrahydrofuran would be expected to lead to higher proportions of tetrahydro compounds. It appears, therefore, that the nature of the solvent plays a certain role in determining the composition of the reaction mixture from the reductions.

The formation of tetrahydroquinolines by reduction of quinolinium salts by either of the hydrides under consideration obviously involves reduction of a carbon-carbon bond in the hetero ring. Under ordinary conditions the isolated carbon-carbon double bond in olefins and other compounds is quite resistant to reduction by either lithium aluminum hydride or sodium borohydride. Under forcing conditions it is possible to accomplish reduction of such double bonds. Ziegler[8] has reported reduction of ethylene and other α-olefins to alkanes with lithium aluminum hydride. Reduction of cinnamyl alcohol has also been described.[9]

The double bond in such aromatically conjugated systems as $\mathrm{Ar\overset{|}{C}{=}\overset{|}{C}{-}N{<}}$ or $\mathrm{Ar\overset{|}{C}{=}\overset{|}{C}{-}\overset{|}{C}{=}O}$ is generally reduced in addition, if possible, to the conjugated polar group.[10,11] For example, 1-methyl- and 1,3-dimethylindole are reduced to the corresponding indolines in 25–30% yield by lithium aluminum hydride although indole itself is not reduced.[12]

The less reactive sodium borohydride in methanol or water normally does not attack carbon-carbon double bonds.[13] A few instances in which carbon-carbon double bonds have been reduced by potassium borohydride have been reported, e.g. reduction of pyridine methiodide to 1-methyl-1,2,5,6-tetrahydropyridine in aqueous sodium hydroxide[14] and reduction of 1-alkylquinolinium and -isoquinolinium halides to tetrahydro derivatives.[15] Apparently no dihydro compounds were isolated from the products of these reductions.

A reasonable explanation for the formation of tetrahydroquinolines as well as dihydroquinolines in these reductions can be formulated on the basis of electron distribution in the pyridine ring of

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(8) K. Ziegler, *Angew. Chem.*, **64**, 323 (1952).

(9) F. A. Hochstein and W. G. Brown, *J. Am. Chem. Soc.*, **70**, 3484 (1948).

(10) W. G. Brown in *Org. Reactions*, **6**, 469 (1951).

(11) N. G. Gaylord, *Reduction with Complex Metal Hydrides*, Interscience, New York, 1956.

(12) P. L. Julian and H. C. Printy, *J. Am. Chem. Soc.*, **71**, 3206 (1949).

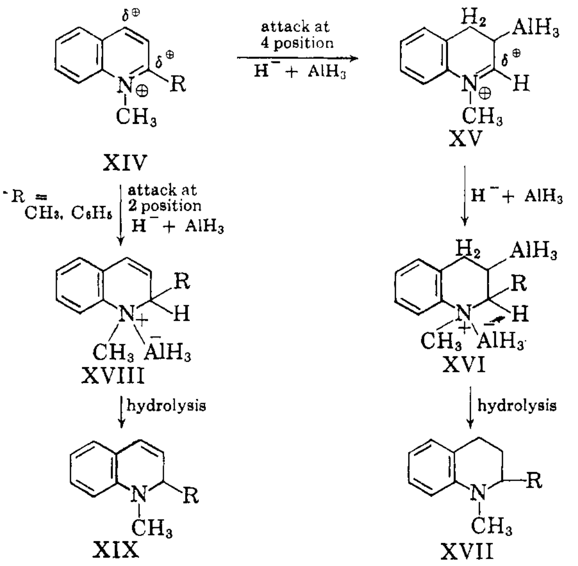
(13) S. W. Chaikin and W. G. Brown, *J. Am. Chem. Soc.*, **71**, 122 (1949).

(14) J. J. Panouse, *Compt. rend.*, **233**, 260 (1951).

(15) R. Torossian, *Compt. rend.*, **235**, 1312 (1952).

quinolinium salts in which electron deficiencies occur at the 2- and 4- positions.[16,17]

It follows that attack by the nucleophilic reagent would then occur at one or the other of these positions. Whether the attacking species is an aluminohydride ion as favored by Trevoy and Brown[18] or the hydride ion itself as favored by Schmid and Karrer[7] and by Paddock[19] is immaterial. In either case the course of the reduction can be formulated as proceeding by simultaneous attack on the susceptible positions as shown by XIV-XVII and XIV-XIX.



If the initial attack is at the 4- position of XIV, the product (XV) would still possess electron deficiency at the 2- position and would be susceptible to further attack by the nucleophile at that position to give XVI, which on hydrolysis would lead to the tetrahydroquinoline (XVII). On the other hand, if initial attack is at the 2- position, the product (XVIII) would no longer be appreciably electron deficient at the 4- position, with further nucleophilic attack unlikely. Hydrolysis of XVIII would then lead to the dihydroquinoline (XIX). This interpretation is supported by the observation that only unchanged 1,2-dimethyl-1,2-dihydroquinoline was recovered when it was subjected to the action of lithium aluminum hydride. While such considerations account satisfactorily for the formation of the products observed, they fail to provide a basis for an explanation for the pronounced effect of the nature of the anion of the quinolinium salts, and of the effect of solvent on the ratio of the products. Such an explanation must await accumulation of additional data.

EXPERIMENTAL[20,21,22]

1-Methyl-2-phenyl-1,2-dihydroquinoline (IX). Phenylmagnesium bromide was prepared from 11.5 g. (0.5 g. atom) of magnesium turnings and 78.5 g. (0.5 mole) of bromobenzene in 400 ml. of absolute ether under a nitrogen atmosphere in a 3-necked flask equipped with a stirrer and reflux condenser. To the reagent was added gradually from an Erlenmeyer flask attached by a short piece of Gooch crucible tubing 27.1 g. (0.1 mole) of quinoline methiodide.[23] The mixture was stirred overnight under nitrogen. After chilling in ice, 150 ml. of 15% acetic acid was added dropwise and the mixture was stirred until two clear layers resulted. After separation, the aqueous layer was extracted several times with ether and the combined ether extracts were dried over anhydrous potassium carbonate. Distillation of the residue after removal of the solvent at reduced pressure under nitrogen gave 10.8 g. of a pale yellow oil, b.p. 124–126° (0.1 mm.), which soon solidified in the receiver. After recrystallization from dilute methanol, the substance formed colorless needles, m.p. 87–88°, which darkened after a few hours exposure to air. Reported m.p. of IX is 89–90°.[3,7]

The *methiodide* was prepared by heating IX with excess methyl iodide in a sealed tube at 60° for several days. After recrystallization from absolute ethanol-petroleum ether (90–100°) it formed yellow needles, m.p. 218° (dec.)

Anal. Calcd. for $C_{16}H_{15}N{\cdot}CH_3I$: C, 56.2; H, 5.00; N, 3.86. Found: C, 56.2; H, 5.08; N, 3.81.

1-Methyl-2-phenyl-1,2,3,4-tetrahydroquinoline (X). To a stirred solution of 1.0 g. of IX in 30 ml. of absolute ethanol under nitrogen, 2.0 g. of freshly cut sodium was slowly added in small pieces with application of sufficient heat to maintain a moderate reflux. After removal of the solvent under reduced pressure the residue was extracted with ether. After drying over anhydrous potassium carbonate and removal of the solvent, distillation gave 0.50 g. of a light orange oil, b.p. 131° (0.3 mm.) which solidified on cooling. Recrystallization from dilute methanol gave white needles, m.p. 102°. Reported m.p. 106–107°.[3,7,24]

Anal. Calcd. for $C_{16}H_{17}N$: C, 86.1; H, 7.67; N, 6.27. Found: C, 86.1; H, 7.53; N, 6.10.

The *methiodide* prepared as above formed pale yellow needles, m.p. 175–176°, after recrystallization from methanol-acetone–petroleum ether (90–100°).

Anal. Calcd. for $C_{16}H_{17}N{\cdot}CH_3I$: C, 55.9; H, 5.52; N, 3.84. Found: C, 55.9; H, 5.58; N, 3.93.

1-Methyl-2-phenyldecahydroquinoline. When 3.0 g. of IX was reduced over 150 mg. of platinum oxide in ethanol, four equivalents of hydrogen were absorbed during 12 days with no apparent break in the rate after absorption of one equivalent. Recrystallization of the product from dilute acetone and dilute methanol gave white crystals, m.p. 63.5–65.0°, of what is believed to be the decahydroquinoline. The infrared spectrum showed no bands in the 1600–1680 cm.$^{-1}$ (aromatic ring) and at 691 cm.$^{-1}$ (monosubstituted benzene).

Anal. Calcd. for $C_{16}H_{23}N$: C, 83.8; H, 10.1. Found: C, 84.0; H, 9.8.

Reduction of 2-phenylquinoline methiodide with lithium aluminum hydride. Modifications of the procedure of Schmid and Karrer[7] were used.

A. To a slurry of 2.4 g. (0.062 mole) of lithium aluminum hydride, in 175 ml. of absolute ether in a flask equipped with a reflux condenser and stirrer under a nitrogen atmos-

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(16) H. C. Longuet-Higgins and C. A. Coulson, *Trans. Faraday Soc.*, **43**, 87 (1947).

(17) B. Pullman, *Bull. soc. chim. France*, 533 (1948).

(18) L. V. Trevoy and W. G. Brown, *J. Am. Chem. Soc.*, **71**, 1675 (1949).

(19) N. L. Paddock, *Nature*, **167**, 1070 (1951).

(20) Microanalyses by Spang Microanalytical Laboratory, Ann Arbor, Mich.

(21) All boiling and melting points are uncorrected.

(22) Infrared spectra were taken on a Perkin-Elmer Model 21 double beam spectrophotometer. Ultraviolet spectra were taken on a Cary Model 11 spectrophotometer.

(23) W. Marckwald and E. Meyer, *Ber.*, **33**, 1884 (1900); A. Hantzsch, *Ber.*, **42**, 68 (1909).

(24) G. Heller, *Ber.*, **47**, 2893 (1914).

phere, 20.4 g. (0.059 mole) of 2-phenylquinoline methiodide[25] was added in small portions, from an Erlenmeyer flask attached by a short piece of Gooch crucible tubing. A somewhat exothermic reaction ensued and the yellow methiodide was decolorized instantly. After stirring at room temperature for 30 min., the mixture was cautiously poured onto crushed ice covered by a layer of ether. The upper layer was separated and the lower aqueous layer was filtered through diatomaceous earth and repeatedly extracted with ether. The filter cake was also extracted with ether. After drying the combined ether portions over anhydrous potassium carbonate, removal of the solvent under nitrogen left a dark residue which on distillation under nitrogen gave 8.5 g. of yellow oil, b.p. 127–128° (0.1 mm.), which solidified in the receiver. Recrystallization from dilute methanol gave colorless needles, m.p. and mixture m.p. with IX prepared by the Freund reaction was 218° dec.

B. When 6.0 g. (0.017 mole) of 2-phenylquinoline methiodide was reduced with 0.72 g. (0.019 mole) of lithium aluminum hydride as above except that the mixture was refluxed gently for 45 hr., 2.78 g. of viscous yellow oil, b.p. 144–145° (0.5 mm.), which solidified to a slightly oily mass on refrigeration was obtained. Crystalline material free of oil was obtained after a few crystallizations from dilute methanol. Quantitative examination of this material by ultraviolet spectroscopy, by the method described below, indicated that it was a mixture of 1-methyl-2-phenyl-1,2-dihydroquinoline and 1-methyl-2-phenyl-1,2,3,4-tetrahydroquinoline in the molar ratio of 10.1 to 1.

Reduction of 2-phenylquinoline methiodide with sodium borohydride. To a stirred solution of 5.0 g. (0.014 mole) of 2-phenylquinoline methiodide in 100 ml. of absolute methanol under nitrogen, 2.2 g. (0.058 mole) of sodium borohydride was slowly added from an Erlenmeyer flask, as above. The yellow reaction mixture became red and then colorless as the addition of the hydride continued. The flask was chilled in ice water so that the temperature was held at 5–10°. After stirring at room temperature for an additional 24 hr. most of the methanol was removed at the water pump and 150 ml. of 3% sodium hydroxide solution was added dropwise to the stirred mixture. After removal of the remaining methanol the aqueous solution was repeatedly extracted with ether. Removal of the ether from the dried extracts (anhydrous potassium carbonate) and distillation of the residue in vacuo under nitrogen through an 8 cm. Vigreux column gave 1.54 g. of nearly colorless oil, b.p. 136° (0.2 mm.) which soon solidified. Two recrystallizations from dilute methanol gave white crystals, m.p. 99–101°. The ultraviolet spectrum showed that this was a mixture of 1-methyl-2-phenyl-1,2-dihydroquinoline and 1-methyl-2-phenyl-1,2-3,4-tetrahydroquinoline in the molar ratio of 1 to 5.3.

Several more crystallizations from dilute methanol gave white needles, m.p. 102°, identified as 1-methyl-2-phenyl-1,2,3,4,-tetrahydroquinoline by mixture m.p., infrared and ultraviolet spectra.

1,2-Dimethyl-1,2-dihydroquinoline, (XII). This was prepared from 18.2 g. of quinoline methiodide and methylmagnesium iodide from 46 g. of methyl iodide and 7.8 g. of magnesium by the procedure used for IX. The product, 8.9 g. of pale yellow oil, b.p. 54–58° (0.08 mm.), n_{D}^{20} 1.6036, n_{D}^{25} 1.6014, rapidly darkened in air. Freund and Richard[3] report n_{D}^{19} 1.5883.

Anal. Calcd. for $C_{11}H_{13}N$: C, 83.0; H, 8.23; N, 8.80. Found: C, 82.8; H, 8.01; N, 8.91.

The *methiodide* formed pale yellow platelets, m.p. 140–141° (dec.), from absolute ethanol-petroleum ether (90–100°).

Anal. Calcd. for $C_{11}H_{13}N{\cdot}CH_3I$: C, 47.9; H, 5.36; N, 4.65. Found: C, 47.9; H, 5.29; N, 4.74.

1,2-Dimethyl-1,2,3,4-tetrahydroquinoline (XIV). This was prepared by sodium and alcohol reduction by the procedure used for X. The product was a pale yellow oil, b.p. 63–64° (0.2 mm.), n_{D}^{20} 1.5721. Reported n_{D}^{19} 1.5678.[4]

Anal. Calcd. for $C_{11}H_{15}N$: C, 81.9; H, 9.38; N, 8.69. Found: C, 81.9; H, 9.31; N, 8.69.

The *methiodide* formed white needles, m.p. 202.5–203° (dec.) from absolute ethanol-petroleum ether (90–100°). Reported m.p. 205°.[4]

Anal. Calcd. for $C_{11}H_{15}N{\cdot}CH_3I$: C, 47.5; H, 5.98; N, 4.62. Found: C, 47.7; H, 6.08; N, 4.55.

2-Methylquinoline methochloride. To 20 g. of 2-methylquinoline in a Carius tube chilled to −70° in a bath of solid carbon dioxide was added 15 ml. of liquid methyl chloride. The tube was sealed, allowed to come slowly to room temperature and then heated for several days at 80°. After chilling to −70°, the tube was opened carefully and the contents were taken up in absolute ethanol. Addition of petroleum ether (90–100°) gave 26.1 g. of product. Further recrystallization from methanol-acetone–petroleum ether (90–100°) gave light violet crystals, m.p. 220–221° (dec.).

Anal. Calcd. for $C_{10}H_9N{\cdot}CH_3Cl$: C, 68.2; H, 6.25; N, 7.23. Found: C, 67.9; H, 6.49; N, 7.11.

2-Methylquinoline methobromide. This was prepared by the procedure used for the methochloride. The very hygroscopic salt formed white needles, m.p. 201–201.5° dec. from methanolacetone. For analysis it was dried over phosphorus pentoxide at 70° and 1 mm.

Anal. Calcd. for $C_{10}H_9N{\cdot}CH_3Br$: C, 55.5; H, 5.08; N, 5.88. Found: C, 55.4; H, 5.21; N, 5.91.

1,2-Dimethylquinolinium bisulfate. To a solution of 33 g. (0.26 mole) of dimethyl sulfate in 200 ml. of anhydrous ether, in a flask equipped with a stirrer and reflux condenser, 30 g. of 2-methylquinoline was added dropwise at such a rate as to maintain a gentle reflux during which a white granular precipitate slowly separated. After refluxing with stirring overnight the solid was collected and washed with ether. The yield of crude product (probably 1,2-dimethylquinolinium methosulfate) was 38.8 g. It was recrystallized from ethanol-water-acetone during which it was converted to deliquescent 1,2-dimethylquinolinium bisulfate, colorless needles, m.p. 228–228.5° dec., presumably by hydrolysis of the methyl sulfate anion. For analysis the salt was dried over phosphorus pentoxide at 75°.

Anal. Calcd. for $C_{10}H_9N{\cdot}CH_3HSO_4$: C, 51.8; H, 5.13; N, 5.49. Found: C, 51.8; H, 5.28; N, 5.61.

Lithium aluminum hydride and sodium borohydride reduction of 2-methylquinoline methiodide. This was done with 25 g. of the methiodide in ether by essentially the procedure used for the reduction of 2-phenylquinoline methiodide. The crude product was distilled through an 8 cm. Vigreux column yielding 12.1 g. of a pale yellow oil, b.p. 59–60° (1 mm.), which rapidly darkened in air. By ultraviolet spectroscopy the oil consisted of a mixture of 1,2-dimethyl-1,2-dihydroquinoline and 1,2-dimethyl-1,2,3,4-tetrahydroquinoline in the molar ratio of 13.3 to 1.

Conversion of a portion of the product to the methiodide resulted in the isolation of the methiodide of 1,2-dimethyl-1,2,3,4-tetrahydroquinoline.

When the reduction was carried out in tetrahydrofuran, no detectable amount of the tetrahydroquinoline was present in the product. The methiodide prepared from the product was identical with that of 1,2-dimethyl-1,2-dihydroquinoline.

Reduction with sodium borohydride in absolute methanol essentially as described for the reduction of 2-phenylquinoline methiodide gave the dihydro- and tetrahydroquinolines in a molar ratio of 6.1 to 1.

Lithium aluminum hydride reduction of the other quinolinium salts. These were done essentially as described for the reduction of 2-methylquinoline methiodide. Results and any significant departures from the procedure are summarized in Table I.

Analysis of mixtures of 1,2-dihydro- and 1,2,3,4-tetrahydroquinolines by ultraviolet spectroscopy. An outline of the method and sample data will be given. Further details can be found in Dr. Wark's dissertation.[1]

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(25) O. Doebner and W. v. Miller, *Ber.*, **16**, 1664 (1883).

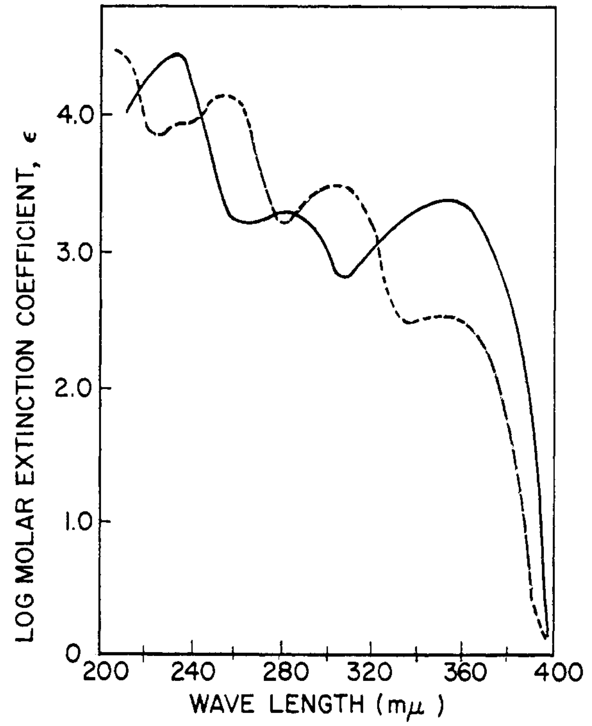

Fig. 1. Ultraviolet absorption spectra: ——— 1,2-dimethyl-1,2-dihydroquinoline. -------- 1,2-dimethyl-1,2,3,4-tetrahydroquinoline. In 95% ethanol.

The ultraviolet absorption spectra of carefully weighed amounts of pure 1,2-dimethyl-1,2-dihydroquinoline and 1,2-dimethyl-1,2,3,4-tetrahydroquinoline in 95% ethanol were taken at several different concentrations (Fig. 1). A plot of optical density versus concentration at several different wave lengths gave straight lines showing that these solutions obeyed Beer's law.

The ultraviolet spectrum of the product of the reduction of 1,2-dimethylquinolinium bromide by lithium aluminum hydride in refluxing ether was determined and gave the following data.

	λ(Å)	D	E	E′	l(cm.)
λ_1	2555	0.20	2.45×10^3	1.17×10^4	1.003
λ_2	2315	0.94	3.74×10^4	6.96×10^3	1.003

where D is the optical density in 95% ethanol, E, and E′ are the molar extinction coefficients of similar solutions of pure 1,2-dimethyl-1,2-dihydroquinoline and pure 1,2-dimethyl-1,2,3,4-tetrahydroquinoline respectively and l is the thickness in cm. of the absorbing solution.

The concentration of the dihydroquinoline, C, was then calculated by substitution in the equation

$$C = \frac{D_{\lambda_2}E'_{\lambda_1} - D_{\lambda_1}E'_{\lambda_2}}{l(E_{\lambda_2}E'_{\lambda_1} - E'_{\lambda_2}E_{\lambda_1})} = 2.28 \times 10^{-5} \text{ moles/l.}$$

and the concentration of the tetrahydroquinoline by substitution in the equation

$$C' = \frac{D_{\lambda_2}E_{\lambda_1} - D_{\lambda_1}E_{\lambda_2}}{l(E_{\lambda_1}E'_{\lambda_2} - E_{\lambda_2}E'_{\lambda_1})} = 1.26 \times 10^{-5} \text{ moles/l.}$$

The mole per cent of dihydroquinoline in the mixture is then 64.4 and that of the tetrahydroquinoline is 35.6.

As a check on the accuracy of the method a synthetic mixture containing 75.5 mole per cent of the pure dihydroquinoline was examined. Using values of λ_1 = 2555 Å and λ_2 = 2315 Å the mole per cent of the two found in the mixture was 71.6 and 28.4 respectively. With λ_1 = 3505 Å and λ_2 = 3060 Å the values found were 71.8 and 28.2. The per cent error in this method based on Beer's law is thus 15.5 for the tetrahydro compound and 5.0 for the dihydro compound. Despite these relatively large errors, the data given in Table I are well within these limits and are therefore considered significant.

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[Contribution from the Chemical Research Department, Central Research Division, American Cyanamid Co.]

Pyrimidine Syntheses. I. Reaction of s-Triazine with Imidates and Amidines Containing an Acidic α-Methylene Group

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Reactions of *s*-triazine with amidines, amidine salts, and imidates having acidic α-methylene groups produce 5-substituted 4-aminopyrimidines in good yield. The corresponding imidate hydrochlorides and thioimidate hydrochlorides give 4-alkoxy- and 4-alkylthiopyrimidines, respectively.

Study of the reactions of *s*-triazine (I) with nucleophilic reagents has been a profitable approach to new synthetic uses for this versatile substance. Grundmann and his associates, for example, have reported several examples of reactions of I with amino compounds leading to substituted formamidines and heterocyclic compounds.[1] From our own work, reactions of I with amidines[2] and imidates[3] which produce substituted *s*-triazines have been reported. This and the following paper[4] deal with

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(1) (a) Ch. Grundmann and A. Kreutzberger, *J. Am. Chem. Soc.*, **77**, 6559 (1955). (b) Ch. Grundmann and R. Rätz, *Chem. Ber.*, **91**, 1766 (1958). (c) Ch. Grundmann and R. Rätz, *J. Org. Chem.*, **21**, 1037 (1956).

(2) F. C. Schaefer and G. A. Peters, *J. Am. Chem. Soc.*, **81**, 1470 (1959).

(3) F. C. Schaefer and G. A. Peters, *J. Org. Chem.*, **26**, 2784 (1961).

(4) K. R. Huffman, F. C. Schaefer, and G. A. Peters, *J. Org. Chem.*, **27**, 551 (1962).