[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, FACULTY OF SCIENCE, FOUAD I UNIVERSITY]

Reactions of *o*-Quinone Monoximes, Monoimines and Triketoindane-2-oxime

BY AHMED MUSTAFA AND MOHAMED KAMEL

RECEIVED MAY 18, 1953

o-Quinone monoximes (Ia, IIa, IIb) react with arylmagnesium halides to give the corresponding 10-arylhydroxylamino-9-hydroxy derivatives of phenanthrene (IIIa–IIId) and 6(or 5)-phenylhydroxylamino-5(or 6)-hydroxychrysene (IVa, IVb), respectively; phenanthraquinone monoimine (Ib) yields the corresponding 10-arylamino-9-hydroxyphenanthrenes (Va–Vc); and triketoindane-2-oxime (VIII) the corresponding 1,3-diaryl-1,3-dihydroxy derivatives of indane-2-one oxime (IXa–IXc). Ia and Ib are reduced by magnesium–magnesium iodide, by lithium aluminum hydride, and by thiophenol; the reduction products are identified.

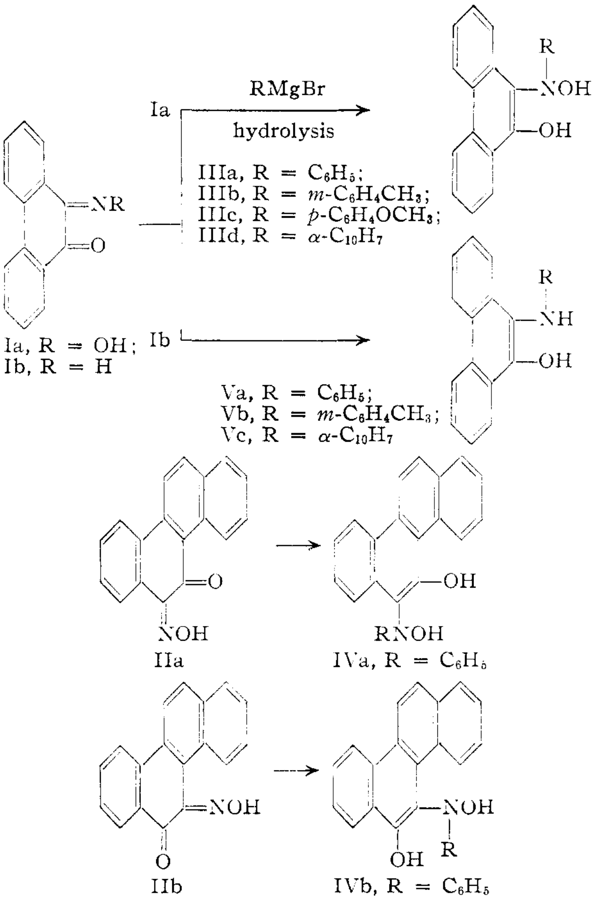
Action of Grignard Reagents on *o*-Quinone Monoximes and Monoimines.—The work of one of us[1,2] on the action of Grignard reagents has been continued in this study of the action of arylmagnesium halides on *o*-quinone monoximes and *o*-quinone monoimines. When phenanthraquinone monoxime (Ia) was treated with an excess of phenylmagnesium bromide and the product hydrolyzed, 10-phenylhydroxylamino-9-hydroxyphenanthrene (IIIa) was obtained. Similarly, 10-*m*-tolyl (IIIb), 10-*p*-methoxyphenyl (IIIc), and 10-α-naphthylhydroxylamino-9-hydroxyphenanthrene (IIId) have been obtained by the action of *m*-tolyl-, *p*-methoxyphenyl- and α-naphthylmagnesium bromides, respectively, on Ia. The reaction of phenylmagnesium bromide on chrysenequinone monoxime (IIa or IIb) gave rise to 6(or 5)-phenylhydroxylamino-5(or 6)-hydroxychrysene (IVa or IVb).

Phenanthraquinone monoimine (Ib) reacted with phenyl-, *m*-tolyl- and α-naphthylmagnesium halides to give, upon hydrolysis, the corresponding 10-arylamino-9-hydroxyphenanthrenes (Va), (Vb) and (Vc), respectively.

IIIa was taken as an example of compounds IIIa-IIId which are obviously of analogous structure. Its structure was inferred from the fact that it is colorless, contains two active hydrogen atoms, dissolved in hot aqueous sodium hydroxide solution, formed a dibenzoyl derivative with benzoyl chloride in the presence of aqueous sodium hydroxide, and gave the expected molecular weight.

Similarly, the structure of Va (taken as an example of compounds Va-Vc) was deduced from the fact that it is colorless, contains two active hydrogen atoms, formed a dibenzoyl derivative with benzoyl chloride in the presence of pyridine, and gave the expected molecular weight. It was identical with an authentic sample of 10-phenylamino-9-hydroxyphenanthrene (Va), prepared by the action of aniline on 9,10-dihydroxyphenanthrene.[3]

IIIa was readily reduced by lithium aluminum hydride[4] to Va, which was found to be identical with the product obtained by the action of phenylmagnesium bromide on Ib and with an authentic sample of Va.[3]



Since IIIa, its dibenzoyl derivative and Va may be considered as structurally related to cyclized α,β-disubstituted stilbenes[5] and to derivatives of 10-amino-9-phenanthrol (Morphigenine),[6] they were tested for estrogenic and narcotic activity.[7] Doses of 1 mg. of these compounds gave no estrogenic response in ovariectomized mice.[8]

Reduction Reaction with: (a) Magnesium–Magnesium Iodide.—A mixture of magnesium and magnesium iodide, which has been so effective in the reduction of 1,2-diketones[9] (*e.g.*, of benzil to

---

[1] A. Mustafa and A. M. Gad, *J. Chem. Soc.*, 384 (1949); A. Mustafa, *ibid.*, 1662, 2151 (1949); A. Mustafa and M. K. Hilmy, *ibid.*, 1339 (1952); and A. Mustafa and O. H. Hishmat, THIS JOURNAL, **75**, 4647 (1953).

[2] *Cf.* the action of Grignard reagents on derivatives of *p*-quinone imides described in A. Mustafa and M. Kamel, *ibid.*, **75**, 2939 (1953).

[3] J. Schmidt and H. Lumpp. *Ber.*, **43**, 787 (1910).

[4] R. F. Nystrom and W. G. Brown, THIS JOURNAL, **70**, 3738 (1948).

[5] For estrogenic activity of stilbene and its derivatives, see U. V. Solmssen, *Chem. Revs.*, **37**, 537 (1945); C. K. Bradsher and W. J. Jackson, THIS JOURNAL, **74**, 4880 (1952).

[6] For the narcotic action of 10-amino-9-phenanthrol see E. Vahlen, *Arch. Exp. Pathol. Pharmac.*, **47**, 368 (1902); *Chem. Zentr.*, **73**, **I**, 1302 (1902).

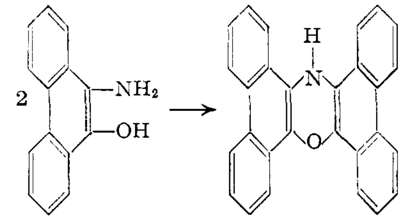
[7] The results will be published later.

[8] Reported by J. M. Robson, Department of Pharmacology, Guy's Hospital, London.

[9] M. Gomberg and W. E. Bachmann, THIS JOURNAL, **49**, 2584 (1927).

benzoin) and of derivatives of *p*-quinone imides (*e.g.*, of 1,4-naphthoquinone dibenzenesulfonimide[2] to naphthalene-1,4-dibenzenesulfonamide), likewise reduced Ia and Ib to 10-amino-9-phenanthrol (VIa). Diphenanthroöxazine (VIb) also has been isolated from the reaction mixture; it is believed to be formed from the primary product VI by autocondensation.[10]

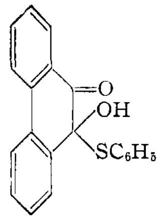
2 Ia or Ib $\xrightarrow{(Mg + MgI_2)}$



VIa VIb

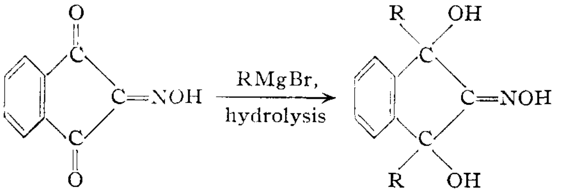
(b) **Lithium Aluminum Hydride.**—Lithium aluminum hydride reduces *o*-quinones (*e.g.*) phenanthraquinone[4] to 9,10-dihydroxyphenanthrene), derivatives of *p*-quinone imides (*e.g.*, 1,4-naphthoquinone dibenzenesulfonimide[2] to naphthalene-1,4-dibenzenesulfonamide) and oximes (*e.g.*, benzaldoxime[11] to benzylamine). It was found to reduce α-benzil monoxime to α,β-diphenyl-β-aminoethanol and Ia and Ib to VIa.

(c) **Thiophenol.**—VIb was obtained in an almost quantitative yield by the action of thiophenol on solid Ia and Ib. The reaction proceeded with great velocity. When thiophenol was added dropwise to a cold benzene solution of Ia or Ib, a mixture of VIa and VIb was formed. The facile reduction of Ia and Ib by thiophenol should be contrasted with its action on phenanthraquinone, which results in the formation of an addition product VII.[12]



VII

Action of Grignard Reagents on Triketoindane-2-oxime (VIII).—When VIII reacted with phenyl-, *m*-tolyl- or *p*-methoxyphenylmagnesium halide, followed by hydrolysis, 1,3-diphenyl- (IXa), 1,3-di-(*m*-tolyl)-(IXb) and 1,3-di-(*p*-methoxyphenyl)-1,3-dihydroxyindane-2-one oxime (IXc) were obtained, respectively.



VIII IXa, R = C_6H_5; IXb, R = m-$C_6H_4CH_3$; IXc, R = p-$C_6H_4OCH_3$

The structure of IXa, which was taken as an example of compounds IXa-IXc, was inferred from the fact that it is colorless, contains three active hydrogen atoms, gave the expected molecular weight, was readily oxidized by nitric acid to *o*-dibenzoylbenzene,[13] and formed 1,3-diphenylindane-2-one when its acetic acid solution was refluxed with hydroiodic acid.[14]

On the other hand, when VIII was refluxed with nitric acid, phthalonic and phthalic acid were obtained.[15] Phthalic acid also has been obtained by the action of nitric acid on triketohydrindane hydrate (ninhydrin) under the same experimental conditions.

Experimental

Action of Grignard Reagents on: (A) *o*-Quinone Monoximes (Ia[16], IIa and IIb[17]).—To a Grignard solution (prepared from 0.9 g. of magnesium and 9 g. of bromobenzene in 50 ml. of dry ether) was added a solution of 1 g. of Ia in 50 ml. of dry benzene. This procedure is also applicable to IIa and IIb. The water was removed from the reflux condenser and the ether was evaporated from the reaction mixture, which then was heated for three hours on a steam-bath. After the mixture had stood overnight at 25°, it was poured slowly into 100 ml. of saturated aqueous ammonium chloride solution, and the reaction mixture extracted with ether. The ether–benzene mixture was dried (Na_2SO_4), filtered and evaporated. The solid residue, upon crystallization, gave colorless crystals which were identified as IIIa.

The 10-arylhydroxylamino-9-hydroxy derivatives of phenanthrene (IIIa–IIId) and 6(or 5)-phenylhydroxylamino-5-(or 6)-hydroxychrysene (IVa or IVb) are listed in Table Ia. They give a blue color with concentrated sulfuric acid; IVa or IVb gives a prussian blue color. They dissolve in warm aqueous sodium hydroxide to give colorless solutions. In general, they are soluble in chloroform and hot benzene; they are readily crystallized from the latter, but are sparingly soluble in light petroleum (b.p. 50–60°).

Action of Benzoyl Chloride on (IIIa).—To a cooled solution of 1 g. of IIIa in about 40 ml. of hot aqueous sodium hydroxide (25%) was added 2 ml. of benzoyl chloride. The reaction mixture was shaken well, decanted from the separated oil and the oil washed with cold water. The colorless solid (0.34 g.), obtained by treating the oil with a few ml. of ether, was filtered off, and crystallized from benzene, m.p. 232–233°. Calcd. for $C_{34}H_{23}O_4N$: C, 80.2; H, 4.5; N, 2.8; mol. wt., 509. Found: C, 79.9; H, 4.6; N, 2.6; mol. wt. (micro-Rast), 489. The dibenzoyl derivative of IIIa is soluble in hot benzene, but difficultly soluble in cold ethyl alcohol; it gives a blue color with concentrated sulfuric acid.

(B) Phenanthraquinone Monoimine (Ib).[18]—A solution of 1 g. of Ib in 30 ml. of dry benzene was added to a solution of phenylmagnesium bromide (prepared as described above). The pale green reaction mixture was refluxed for two hours (steam-bath) and set aside overnight at room temperature. It was worked up as described above. The ether–benzene mixture was concentrated and the crystals, that separated upon the addition of about 5 ml. of light petroleum (b.p. 50–60°), were filtered off. Recrystallization from a mixture of benzene and light petroleum (b.p. 50–60°) gave colorless crystals which were identified as Va (m.p. and mixed m.p.

---

[10] *Cf.* the reduction of Ia and Ib by the action of isopropyl alcohol in sunlight (A. Schönberg, *et al.*, *J. Chem. Soc.*, 374 (1950)).

[11] E. Larsson, *Svensk Kem. Tid.*, **61**, 242 (1949); *C. A.*, **44**, 1898 (1950).

[12] A. Schönberg and O. Schütz, *Ber.*, **60**, 2344 (1927).

[13] *Cf.* the formation of *o*-dibenzoylbenzene by the action of nitric acid on 1,2,3-trihydroxy-1,2,3-triphenylindane in R. Moubasher, *et al.*, *J. Chem. Soc.*, 1998 (1950).

[14] *Cf.* the formation of 1,3-diphenylindane-2-one by the action of hydroiodic acid on an acetic acid solution of 1,3-diphenyl-3-hydroxyindane-2-one in C. F. Koelsch, THIS JOURNAL, **58**, 1321 (1936).

[15] This is in contrast to the finding of W. O. Teeters and R. L. Shriner, THIS JOURNAL, **55**, 3026 (1933), that VIII is recovered unchanged when refluxed with various percentages of dilute sulfuric acid (5–35%).

[16] H. Goldschmidt, *Ber.*, **16**, 2176 (1883).

[17] C. Graebe and F. H. Hönigsberger, *Ann.*, **311**, 259 (1900).

[18] J. Schmidt and E. Junghans, *Ber.*, **37**, 3556 (1904).

TABLE Ia

10-ARYLHYDROXYLAMINO-9-HYDROXY DERIVATIVES OF PHENANTHRENE (IIIa–IIId) AND (IVa OR IVb)

Compound	M.p., °C.	Yield, %	Formula	Analyses, % Carbon		Hydrogen		Nitrogen		Active H	
				Calcd.	Found	Calcd.	Found	Calcd.	Found	Calcd.	Found
IIIa	158	72	$C_{20}H_{15}O_2N^a$	79.7	79.5	4.98	4.8	4.7	4.7	0.66	0.65
IIIb	186	78	$C_{21}H_{17}O_2N$	80.0	79.9	5.4	5.3	4.4	4.2	.63	.61
IIIc	178	65	$C_{21}H_{17}O_3N$	76.1	75.9	5.1	4.8	4.2	4.2	.60	.58
IIId	192	81	$C_{24}H_{17}O_2N$	82.1	82.0	4.8	4.6	3.98	3.7	.57	.54
IVa or IVb	202	83	$C_{24}H_{17}O_2N$	82.1	81.9	4.8	4.7	3.98	3.8	.57	.56

[a] Mol. wt., calcd. 301. Found: mol. wt. (micro-Rast), 298.

TABLE Ib

10-ARYLAMINO-9-HYDROXY DERIVATIVES OF PHENANTHRENE (Va–Vc)

Va	163	71	$C_{20}H_{15}ON^a$	84.2	84.1	5.3	5.1	4.9	4.8	0.70	0.68
Vb	172	78	$C_{21}H_{17}ON$	84.3	84.3	5.7	5.5	4.7	4.7	.66	.64
Vc	177	75	$C_{24}H_{17}ON$	86.0	85.6	5.1	4.9	4.2	4.1	.59	.57

[a] Mol. wt., calcd. 285. Found: mol. wt. (micro-Rast), 278.

TABLE Ic

1,3-DIARYL-1,3-DIHYDROXY DERIVATIVES OF INDANE-2-ONE OXIME (IXa–IXc)

IXa	212	65	$C_{21}H_{17}O_3N^a$	76.1	76.0	5.1	5.0	4.2	4.1	0.91	0.89
IXb	190	69	$C_{22}H_{19}O_3N$	76.5	76.3	5.5	5.4	4.1	3.9	.87	.88
IXc	168	62	$C_{22}H_{19}O_4N$	73.1	73.0	5.3	5.1	3.9	3.8	.83	.81

[a] Mol. wt., calcd. 331. Found: mol. wt. (micro-Rast), 326.

with an authentic sample[3]). Va was recovered unchanged when treated with lithium aluminum hydride according to the procedure described below for IIIa.

The 10-arylamino-9-hydroxy derivatives of phenanthrene (Va–Vc) are listed in Table Ib. They give an olive-green color with concentrated sulfuric acid; when the solution of Va in concentrated sulfuric acid is treated with a crystal of potassium nitrate, a wine-red color is produced.[3] They are soluble in ethyl alcohol, chloroform and benzene, but difficultly soluble in light petroleum (b.p. 50–60°). They are readily crystallized from benzene–light petroleum (b.p. 50–60°).

Action of Benzoyl Chloride on Va.—To a solution of 0.5 g. of Va in 15 ml. of pyridine was added 4 ml. of benzoyl chloride, and the mixture was heated (steam-bath) for two hours. It was poured into 50 ml. of dilute hydrochloric acid; the oil that separated was extracted with ether. After the ethereal layer had been washed with about 40 ml. of cold 8% aqueous sodium hydroxide and then with water, it was dried and evaporated. The oily residue was treated with light petroleum (b.p. 50–60°) to give 0.32 g. of colorless crystals, m.p. 217°.

Anal. Calcd. for $C_{34}H_{23}O_3N$: C, 82.8; H, 4.7; N, 2.8; mol. wt., 493. Found: C, 82.7; H, 4.7; N, 2.7; mol. wt. (micro-Rast), 482.

The dibenzoyl derivative of Va gives a green color with concentrated sulfuric acid; it is soluble in benzene, hot alcohol and chloroform, but difficultly soluble in light petroleum (b.p. 50–60°).

Action of Lithium Aluminum Hydride on IIIa.—To 0.7 g. of pulverized lithium aluminum hydride (from New Metals and Chemicals, Ltd., London) was added 50 ml. of dry ether. After 15 minutes, 30 ml. of a benzene solution containing 1 g. of IIIa was added. The reaction mixture was refluxed for three hours and then set aside overnight at room temperature. After treatment with cold aqueous ammonium chloride solution, the ethereal solution was dried and evaporated. The solid residue was crystallized from benzene–light petroleum (b.p. 50–60°) to yield 0.81 g., m.p. 164°, which was identified as Va (m.p. and mixed m.p. with an authentic sample[3] and with a sample of Va prepared by the action of phenylmagnesium bromide on Ib).

Reduction Reactions with: (A) Magnesium–Magnesium Iodide.—To the colorless mixture of 1 g. of magnesium powder, 4 g. of iodine in 20 ml. of dry ether and 20 ml. of dry benzene was added 1 g. each of Ia and Ib. The brown reaction mixture was kept overnight at room temperature with frequent shaking. Then it was poured into 100 ml. of aqueous saturated ammonium chloride and (A), which was insoluble in ether, was filtered off. After the ether–benzene layer had been washed with very dilute aqueous sodium thiosulfate and then with water, it was dried and allowed to evaporate slowly at room temperature. About 0.23 g. of 10-amino-9-phenanthrol (VIa) was obtained and identified as the N-benzoyl derivative[19] (m.p. and mixed m.p.).

The solid (A) was recrystallized from β-methylnaphthalene to give 0.31 g. of diphenanthroöxazine (VI[10]) (m.p. and mixed m.p.).

(B) Lithium Aluminum Hydride.—The procedure described above for the reduction of IIIa to Va by lithium aluminum hydride was used for the reduction of α-benzil monoxime, Ia and Ib. The reaction products, which were crystallized from light petroleum (b.p. 60–80°), were identified, respectively, as α,β-diphenyl-β-aminoethanol[20] (m.p. and mixed m.p.) and VIa (identified as above). The yield was almost quantitative.

(C) Thiophenol.—One gram of Ia (or Ib) was treated with 2 ml. of thiophenol; there was a marked rise in temperature. The reaction was brought to completion by immersing the reaction tube in a steam-bath at 80° for ten minutes. After the reaction mixture had been washed several times with hot benzene (about 30 ml.), the solid residue was crystallized from β-methylnaphthalene to give orange-brown crystals, m.p. 355°, which were identified as VIb (m.p. and mixed m.p.). The yield was almost quantitative.

Anal. Calcd. for $C_{28}H_{17}ON$: C, 87.7; H, 4.4; N, 3.7. Found: C, 87.3; H, 4.2; N, 3.4.

In another experiment, thiophenol was added dropwise to a cold solution containing 1 g. each of Ia and Ib in 15 ml. of benzene, and the reaction mixture was placed in a bath at 10° for ten minutes. The benzene was allowed to evaporate slowly, and the solid that separated was washed twice with light petroleum (b.p. 60–80°). The insoluble residue was crystallized from β-methylnaphthalene yielding 0.22 g. which was identified as VIb. On evaporation, the light petroleum washings gave 0.24 g. of VIa (identified as above).

Action of Grignard Reagents on Triketoindane-2-oxime (VIII).—To a solution of phenylmagnesium bromide (prepared as described in the preparation of IIIa) was added 1 g. of VIII,[15] followed by 30 ml. of dry benzene. The brownish-red reaction mixture was refluxed for two hours and then kept at room temperature overnight. It was worked up as described for IIIa; on evaporation, the ether–benzene layer gave colorless crystals of IXa.

The 1,3-diaryl-1,3-dihydroxy derivatives of indane-2-one oxime (IXa–IXc) are listed in Table Ic. IXa and IXb give a brown-red color with concentrated sulfuric acid; IXc gives a violet color. They are soluble in hot benzene, acetone and chloroform, but difficultly soluble in light pe-

---

(19) K. Auwers, *Ann.*, **378**, 210 (1911).

(20) S. Kanao, *J. Pharm. Soc. Japan*, **49**, 173 (1929).

troleum (b.p. 60–80°); they can be readily crystallized from benzene or toluene.

Action of Nitric Acid on: (A) 1,3-Diphenyl-1,3-dihydroxyindane-2-one Oxime (IXa).—A mixture of 0.5 g. of IXa, 10 ml. of concentrated nitric acid (d. 1.42) and 20 ml. of water was refluxed for two hours. A light-yellow oil was formed which, after cooling, solidified to yield 0.31 g. of material. This was crystallized from benzene–light petroleum (b.p. 50–60°) to give colorless crystals, m.p. 147°, which were identified as *o*-dibenzoylbenzene (m.p. and mixed m.p. with an authentic sample).

(B) **Triketoindane-2-oxime (VIII).**—One-half gram of VIII was treated with nitric acid as described above for IXa. The reaction mixture was allowed to evaporate on a steam-bath and the solid residue was washed with ether (30 ml.); the ether-insoluble fraction was crystallized from water and identified as phthalic acid (0.14 g.) by its m.p., mixed m.p. and the phthalein reaction. On evaporation, the ether washings gave an oil which solidified on treatment with cold light petroleum (b.p. 50–60°); the solid was crystallized from a mixture of benzene and ether to yield 0.24 g. of colorless crystals, m.p. 143–4°, which were identified as phthalonic acid[21] (m.p. and mixed m.p.).

(C) **Triketohydrindane Hydrate (Ninhydrin).**—One gram of the trione was refluxed with nitric acid as described above. The reaction mixture gave, on evaporation, a solid residue (0.34 g.) which proved to be phthalic acid (m.p. and mixed m.p.).

Action of Hydroiodic Acid on IXa.—A solution of 1 g. of IXa in a mixture of 15 ml. of hydroiodic acid (d. 1.7) and 30 ml. of glacial acetic acid, was refluxed for three hours. The cooled reaction mixture was poured onto ice; the solid that separated was filtered off, washed with water, and crystallized from acetic acid to yield 0.51 g. of colorless crystals, m.p. 169°. The compound was identified as 1,3-diphenylindane-2-one (m.p. and mixed m.p. with an authentic sample[14]).

---

[21] J. Tcherniac, *J. Chem. Soc.*, **109**, 1236 (1916).

CAIRO, EGYPT

[CONTRIBUTION FROM THE LILLY RESEARCH LABORATORIES, ELI LILLY AND CO.]

The Willgerodt Reaction Applied to α- and γ-Alkylpyridines

BY HERSCHEL D. PORTER

RECEIVED MAY 23, 1953

It is known that the chemical reactivities of α- and γ-alkylpyridines closely resemble those exhibited by alkyl ketones. It was of interest, therefore, to investigate the possibility that such alkylated pyridines could participate in the Willgerodt reaction. Further, the successful conversion of α- and γ-alkylpyridines to thioamides would involve only oxidative steps; the absence of easily reducible functional groups precludes the occurrence of the Willgerodt reaction by the route of King and McMillan.[1]

The reaction of γ-picoline with sulfur has been thoroughly investigated by Thayer and Corson[2]; the products so obtained are 1,2-di-(4-pyridyl)-ethane, 1,2-di-(4-pyridyl)-ethylene, 1,2,3-tri-(4-pyridyl)-propane, 1,2,3,4-tetra-(4-pyridyl)-thiophene and hydrogen sulfide. The yield of the thiophene derivative is markedly enhanced by the addition of alkali to the reaction mixture.

Recently, Emmert and Groll[3] have discovered that the reaction of α-picoline with sulfur does not give products corresponding to those obtained from γ-picoline; instead a compound $C_{36}H_{24}N_6S_2$ was isolated and its structure elucidated. Further, they[4] report that the reaction of α-picoline, sulfur and either nitrobenzene or aniline gives thiopicolinanilide and 2-(2-pyridyl)-benzothiazole. This final observation prompts the disclosure of the results of an investigation underway in our laboratories.

We have found that thioamides are produced by the reaction of either α- or γ-picoline with sulfur in the presence of an amine. When morpholine was the amine utilized, γ-picoline produced thioisonicotinoyl morpholine in 40% yield while α-picoline produced thiopicolinoyl morpholine in 22% yield. In each case an unidentified sublimate appeared in the condenser. Because of this complication, a further study was made using the picolines, sulfur and aniline. α-Picoline proved to be the most reactive producing the desired thioanilide[4] in 63% yield after twelve hours of heating in an oil-bath maintained at 160°. To obtain a comparable yield with γ-picoline, the oil-bath temperature was increased to 180° and the reaction time prolonged to 24 hours. However, the product isolated proved to be 2-(4-pyridyl)-benzothiazole; this may be regarded as being derived from the expected thioisonicotinanilide by further oxidation with sulfur and ring closure. The supposition that the methyl group must be in an activated position for reaction to take place is supported both by the observation that β-picoline survived attack to the extent of 79% after 24 hours and by the fact that no thionicotinanilide, or related product, could be isolated from the reaction mixture.

The success of the reaction with α- and γ-picolines encouraged us to investigate the reaction with the higher homologs, 4-ethyl- and 4-propylpyridines. The reaction of morpholine with 4-ethylpyridine and sulfur produced the anticipated thiomorpholide; the reaction of aniline with 4-propylpyridine and sulfur produced a benzothiazole derivative in analogy with the reaction of γ-picoline with the same reagents. Although these observations are highly encouraging from the standpoint of expanding the usefulness of the Willgerodt procedure to include compounds containing activated alkyl substituents, it is realized that the products may have arisen *via* the olefin route[5] involving initial dehydrogenation to 4-vinylpyridine and 1-(4-pyridyl)-propene-1, respectively.

The exact limits of the usefulness of this extension of the Willgerodt reaction cannot now be defined. The results of our experiments suggest that the alkyl group must be highly activated in order to

---

[1] J. A. King and F. H. McMillan, THIS JOURNAL, **68**, 632 (1946).

[2] H. I. Thayer and B. B. Corson, *ibid.*, **70**, 2330 (1948).

[3] B. Emmert and M. Groll, *Chem. Ber.*, **86**, 205 (1953).

[4] B. Emmert and M. Groll, *ibid.*, **86**, 208 (1953).

[5] M. Carmack and D. F. DeTar, U. S. Patent 2,495,567 (January 24, 1950).