reaction mixture was refluxed for two hours (water-bath) and kept aside overnight at room temperature. It was decomposed with aqueous ammonium chloride solution, extracted with ether and the ethereal solution was extracted twice with cold aqueous sodium hydroxide solution (8%, *ca.* 40 ml.). The ethereal layer was washed with water, dried and evaporated and the oily residue, which solidified after washing with 40 ml. of light-petroleum (b.p. 50–60°), was recrystallized from petroleum ether (b.p. 80–100°) as colorless crystals, m.p. 201°. *Anal.* Calcd. for $C_{32}H_{26}O_2$: C, 86.9; H, 5.9; active hydrogen (two atoms), 0.45; mol. wt., 442. Found: C, 86.8; H, 5.9; active hydrogen, 0.43; mol. wt. (micro Rast), 436. The yield was *ca.* 1.2 g. It was identified as *o*-bis-(diphenylhydroxymethyl)-benzene (X)[7] (m.p. and mixed m.p. and color reaction with concentrated sulfuric acid which is yellow, turning to reddish-brown).

The light-petroleum (b.p. 50–60°) washings gave, after slow evaporation, colorless crystals (*ca.* 0.36 g.), of biphenyl (m.p. and mixed m.p.).

The aqueous alkaline extract was acidified with dilute hydrochloric acid, extracted with ether, dried and evaporated. The colorless crystals (*ca.* 0.64 g.) thus obtained proved to be benzenesulfonamide (m.p. and mixed m.p.).

(C) **N-Phenylsulfonylnaphthosultam** (XIII, R = SO_2Ph) was prepared as follows: the yellow solution of 1 g. of naphthosulfam[12] (XIII, R = H) in 30 ml. of aqueous potassium hydroxide (25%), was treated with 3 ml. of benzenesulfonyl chloride with continuous stirring. A vigorous reaction took place with the disappearance of the yellow color and the separation of a colorless solid. The reaction mixture was heated (water-bath) for 15 minutes, cooled and filtered and the solid was crystallized from acetic acid and then from benzene as colorless crystals, m.p. 196°. *Anal.* Calcd. for $C_{16}H_{11}O_4NS_2$: C, 55.7; H, 3.2; N, 4.0; S, 18.6; mol. wt., 345. Found: C, 55.6; H, 3.2; N, 3.9; S, 18.4; mol. wt. (micro Rast), 340. The yield was almost quantitative. (XIII, R = SO_2Ph) is difficultly soluble in alcohol and ether and is insoluble in aqueous sodium hydroxide.

(b) To a solution of phenylmagnesium bromide (prepared as above) was added 2 g. of XIII (R = SO_2Ph) and 40 ml. of dry benzene; a yellow precipitate formed after few minutes. The water was removed from the reflux condenser and the ether was evaporated from the reaction mixture, which was heated for three hours on a water-bath. After the mixture had stood overnight at 25°, it was poured slowly into 100 ml. of saturated aqueous ammoniun chloride solution, and the reaction mixture was extracted with ether. The ethereal solution was dried, evaporated and the oily residue which solidified after scratching was washed with cold ether and crystallized from chloroform as colorless crystals, m.p. 196–197° (yellow melt) (mixed m.p. with (XIII, R = SO_2Ph) gave 168°). *Anal.* Calcd. for $C_{22}H_{17}O_4NS_2$: C, 62.4; H, 4.0; N, 3.3; S, 15.1; active hydrogen, 0.24; mol. wt., 423. Found: C, 62.3; H, 4.0; N, 3.3; S, 14.9; active hydrogen, 0.22; mol. wt. (micro Rast), 421. 8-Phenylsulfonyl-1-phenylsulfonylnaphthylamine (XIV) is soluble in hot benzene, but difficultly soluble in alcohol; it dissolves in hot aqueous potassium hydroxide solution with pale-yellow color and gives no color when treated with concentrated sulfuric acid, but on adding one crystal of potassium nitrate a red color is developed. The yield was *ca.* 64%.

A suspension of 0.5 g. of XIV in 30 ml. of ether was treated with an ethereal solution of diazomethane (prepared from 4 g. of nitrosomethylurea) and the reaction mixture was kept at 0° overnight and then treated with a fresh amount of ethereal diazomethane solution, prepared as above. The ether was allowed to evaporate slowly and the solid which separated was crystallized from chloroform–petroleum ether mixture as colorless crystals, m.p. 226°. *Anal.* Calcd. for $C_{23}H_{19}O_4NS_2$: C, 63.2; H, 4.3; N, 3.2; S, 14.6. Found: C, 63.0; H, 4.1; N, 3.1; S, 14.4. The N-methyl derivative of (XIV) is easily soluble in chloroform, but difficultly soluble in ethyl alcohol. It is insoluble in aqueous potassium hydroxide and gives no color reaction when treated with concentrated sulfuric acid. The yield was *ca.* 58%.

(D) **Naphthosultam** (XIII, R = H) **and N-Methylnaphthosultam** (XIII, R = CH_3).—Two grams of each of XIII (R = H)[12] and XIII (R = CH_3)[13] were treated with a solution of phenylmagnesium bromide under the same experimental conditions described in the case of (XIII, R = SO_2-Ph). On working up the reaction mixtures, XIII (R = H) and XIII (R = CH_3) were recovered completely or almost completely unchanged.

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CAIRO, EGYPT

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF FORDHAM UNIVERSITY]

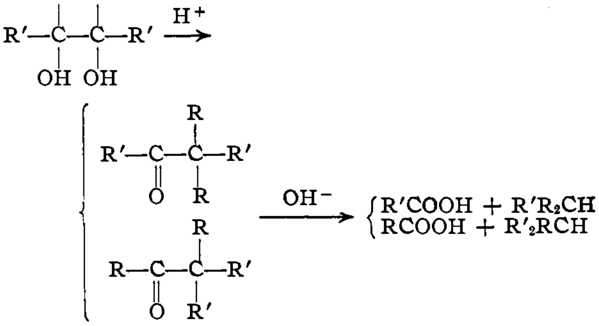
The Pinacol Rearrangement in the Heterocyclic Series. I. Pyridine Analogs of Benzopinacol

BY MATTHEW R. KEGELMAN AND ELLIS V. BROWN

RECEIVED APRIL 11, 1953

Symmetrical analogs of benzopinacol containing two phenyl groups with either two 2-pyridyl groups or two 3-pyridyl groups have been synthesized and rearranged. The structures of the products of rearrangement have been determined by characterization of their degradation products.

Investigators in the past[1] have determined relative migratory aptitudes for some twenty different aryl groups, based on a standard value of unity which was arbitrarily assigned to the phenyl group. This was accomplished by taking advantage of the scheme outlined in reaction 1. If, for example, rearrangement of the pinacol shown gave rise to two parts of the pinacolone where the group R′ has migrated for every one part of the pinacolone where the group R has migrated, then the migratory aptitude of the group R′ was said to be twice that of the



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(1) (a) J. C. Bailar, THIS JOURNAL, **52**, 3596 (1930); (b) W. E Bachmann and F. H. Moser, *ibid.*, **54**, 1124 (1932); (c) W. E. Bachmann, *ibid.*, **54**, 1967 (1932); (d) C. H. Beale and H. H. Hatt, *ibid.*, **54**, 2405 (1932); (e) W. E. Bachmann and W. Ferguson, *ibid.*, **56**, 2081 (1934); (f) W. E. Bachmann and E. Ju-Hwa Chu, *ibid.*, **57**, 1095 (1935); (g) W. E. Bachmann and E. Ju-Hwa Chu, *ibid.*, **58**, 1118 (1936); (h) H. H. Hatt, A. Pilgrim and E. F. M. Stephenson, *J. Chem. Soc.*, 478 (1941); (i) R. Gaertner, *J. Org. Chem.*, **15**, 1006 (1950).

group R. The numerical migratory aptitudes found in this way ranged from negligibly small values found for some ortho substituted phenyl groups to 500 for the *p*-anisyl and *p*-phenetyl groups.

All the aryl groups thus far studied were carboisocyclic. We have continued these studies by extending them to the heterocyclic series. The present report deals with those pinacols wherein the migration of the phenyl group is compared with that of the 2-pyridyl group and with that of the 3-pyridyl group.

It was intended at the outset of our investigation to obtain the required pinacols by treating phenyl heterocyclic aryl ketones with the magnesium–magnesium iodide reducing agent of Gomberg and Bachmann.[2] However, with phenyl 2-, 3- and 4-pyridyl ketones, this reaction has been found to lead to the formation of insoluble complexes between the ketones and the reducing agent, from which nothing can be isolated but the ketones themselves. Therefore, the reduction of these ketones had to be accomplished by other, less satisfactory means.

The 2-pyridyl analog of benzopinacol was obtained in 14% yield by the reduction of phenyl 2-pyridyl ketone in aqueous ethanol with sodium amalgam. The 3-pyridyl analog resulted in 68% yield by the photochemical reduction of the corresponding 3-pyridyl ketone, using 2-propanol. Although it is possible for pinacols of this type to exist in *meso-* and *dl*-forms, there was only one isomer produced in each of these syntheses. Studies in the aliphatic series[3,4] indicate that the nature of the pinacolones obtained is dependent upon the configuration of the pinacols rearranged. In the aromatic series, on the other hand, this factor does not seem to be of major importance.[1i]

In the rearrangement of both of these pinacols, the phenyl group was observed to migrate to the complete exclusion of the pyridyl groups. Cleavage of the pinacolones by boiling alkali furnished only one carboxylic acid and only one triarylmethane in each case. Although the pinacolones are not accounted for quantitatively by the degradation products isolated, it is reasoned that had there been present any of that isomer formed by migration of the pyridine nucleus, its degradation would have given rise to benzoic acid. This substance would then have been separated in the ensuing isolation procedure and identified. The yields of the picolinic and nicotinic acids were determined by potentiometric titration, while the triarylmethanes were characterized by comparison with authentic samples.

The negligibly small values thus found for the migratory aptitudes of the pyridyl groups studied are not entirely unexpected. Their explanation can be based on the same reasoning as is that of the difficulty of electrophilic substitution in the pyridine nucleus.[5] The pyridine ring undoubtedly acquires a positive charge by accepting a proton from the acid rearranging medium. This charge would then prevent the heterocyclic nucleus from approaching the similarly positively charged carbon atom toward which migration takes place in the pinacol rearrangement.

The synthetic routes found workable for the production of the 2- and 3-pyridylpinacol analogs were useless when applied to the reduction of phenyl 4-pyridyl ketone. Reduction with zinc dust and acetic acid, furthermore, furnished not the pinacol but the corresponding hydrol.

It is interesting to note that photochemical reduction of phenyl 4-pyridyl ketone also afforded the hydrol. Although hydrols are the expected products of photochemical reduction in the presence of alkali, they have not been reported when alkali is not used, as was the case here.

Experimental

1,2-Di-(2-pyridyl)-1,2-diphenylethane-1,2-diol.—An 18.3-g. (0.1 mole) sample of phenyl 2-pyridyl ketone[6] was dissolved in 130 ml. of ethanol and the solution cooled in an ice-bath. Water was added carefully to a point just short of turbidity. There was added with mechanical stirring an amalgam of 4.5 g. of sodium and 9.8 ml. of mercury. The mixture was allowed to warm gradually to room temperature and stirring was continued for 12 hours. The fine white crystals which formed were separated and washed very thoroughly with water. The crude pinacol thus obtained, which weighed 2.5 g. (14%), was purified by reprecipitating it three times from dioxane solution with water. The pure pinacol melted at 129–130°. Upon prolonged storage, the compound was observed to decompose gradually to form a brown oil.

Anal. Calcd. for $C_{24}H_{20}O_2N_2$: C, 78.23; H, 5.48. Found: C, 77.91; H, 5.45.

Rearrangement of 1,2-Di-(2-pyridyl)-1,2-diphenylethane-1,2-diol and Scission of the Pinacolone.—To a 3.68-g. (0.01 mole) sample of the pinacol was added a mixture of 80 ml. of dry benzene, 20 ml. of glacial acetic acid and 40 ml. of acetyl chloride. While protected from the atmosphere by a drying tube, the mixture was refluxed for 44 hours, using a heating bath maintained at 90°. The bulk of the volatile material was then removed *in vacuo* (bath at 90°). The residue was freed of the last of the acetic acid by storage in a vacuum desiccator over potassium hydroxide.

The resulting pinacolone residue was next refluxed for 36 hours with a solution of 6.0 g. of potassium hydroxide in 100 ml. of absolute ethanol. Most of the ethanol was removed *in vacuo* (bath at 90°). The last traces of ethanol were removed by storage in a vacuum desiccator over sulfuric acid. To the residue was added 100 ml. of water and the mixture was then extracted exhaustively by shaking with several portions of ether.

The combined ethereal extracts were dried over sodium sulfate and the ether evaporated to leave a residue of 1.47 g. (60%) of crude 2-pyridyldiphenylmethane. After two crystallizations from aqueous ethanol, this material melted at 61–62° and showed no depression in m.p. when mixed with an authentic sample of 2-pyridyldiphenylmethane.[7]

The alkaline aqueous layer from the above extraction was acidified and again extracted with several portions of ether, in order to remove any benzoic acid which may have been present. However, no significant residue remained after these combined ethereal extracts were dried and evaporated.

The aqueous solution was now titrated potentiometrically. The consumption of standard base between the characteristic points of inflection of the resulting curve at *p*H 3.5 and *p*H 8.5 corresponded to 0.0080 mole (80%) of picolinic acid. The pK_a calculated from this curve agreed within experimental error with that given for picolinic acid.

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[2] M. Gomberg and W. E. Bachmann, THIS JOURNAL, **49**, 236 (1927).

[3] (a) P. D. Bartlett and I. Pockel, *ibid.*, **59**, 820 (1937); (b) P. D. Bartlett and A. Bavley, *ibid.*, **60**, 2416 (1938).

[4] E. R. Alexander and D. C. Dittmer, *ibid.*, **73**, 1665 (1951).

[5] A. E. Remick, "Electronic Interpretations of Organic Chemistry," John Wiley and Sons, Inc., New York, N. Y., 1943, p. 106.

[6] R. Wolffenstein and F. Hartwich, *Ber.*, **48**, 2043 (1915).

[7] A. E. Chichibabin and S. E. Benewolenskaja, *ibid.*, **61**, 547 (1928).

1,2-Di-(3-pyridyl)-1,2-diphenylethane-1,2-diol.—A 5.0-g. (0.027 mole) sample of phenyl 3-pyridyl ketone[3] was dissolved in 50 ml. of 2-propanol contained in an 8-inch test-tube. After adding one drop of acetic acid, the tube was sealed in a flame and exposed to direct sunlight for one month. The tube was then opened and the white crystals which had deposited were separated by filtration and washed with alcohol. The resulting 3.4 g. (68%) of pinacol was sufficiently pure to be used directly for rearrangement. For analysis, a small sample was recrystallized from dioxane. The pinacol was only very slightly soluble in this solvent at the boiling point, but precipitated from the cooled solution after standing overnight. The pure pinacol melted at 187–188°.

Anal. Calcd. for $C_{24}H_{20}O_2N_2$: C, 78.23; H, 5.48; N, 7.61. Found: C, 77.92; H, 5.46; N, 7.55.

The pinacol was sparingly soluble in all the ordinary organic solvents with the exception of hot pyridine. It did not darken after prolonged storage.

Rearrangement of 1,2-Di-(3-pyridyl)-1,2-diphenylethane-1,2-diol and Scission of the Pinacolone.—The procedure used was exactly the same as that used for the 2-isomer, except that scission was effected by refluxing with a solution of 25 g. of potassium hydroxide in 100 ml. of methanol.

The 1.52-g. (62%) yield of crude 3-pyridyldiphenylmethane was recrystallized several times from petroleum ether (b.p. 60–70°) to furnish white crystals melting at 75.5–77°. There was no depression in m.p. when this material was mixed with an authentic sample of 3-pyridyldiphenylmethane.[8]

Once again no benzoic acid could be extracted from the acidified aqueous layer. Potentiometric titration of the latter, however, showed the consumption of 0.0079 mole of standard base between the two characteristic points of inflection of the curve at *p*H 3.4 and 8.5. This indicated a 79% yield of nicotinic acid. The pK_a calculated from the curve agreed within experimental error with that given for nicotinic acid.

Phenyl 4-Pyridyl Ketone (Experiment by A. R. Casola).—A 41-g. (0.33 mole) sample of isonicotinic acid, m.p. 309°, was refluxed with 100 ml. of thionyl chloride for 20 hours. Most of the excess thionyl chloride was removed from the dark reaction mixture *in vacuo* and the residue was dissolved in a mixture of 90 ml. (1.0 mole) of dry benzene and 250 ml. of dry carbon disulfide. The solution was refluxed with stirring and 89 g. (0.67 mole) of aluminum chloride was added cautiously in small portions. Heating and stirring were continued for six hours, after which the mixture was cooled and hydrolyzed by pouring onto cracked ice. The entire mass was then subjected to distillation with steam. The residue from the steam distillation was cooled, made basic with 50% sodium hydroxide solution and extracted with 800 ml. of ether used in three portions. The combined extracts were dried over potassium hydroxide, the solvent removed and the residue distilled, b.p. 312–322°. The 40 g. (66%) of pale pink solid was recrystallized from petroleum ether to furnish phenyl 4-pyridyl ketone melting at 72–75°. A mixed m.p. with an authentic sample[9] showed no depression.

Phenyl-4-pyridylcarbinol.—A 5.0-g. (0.029 mole) portion of phenyl 4-pyridyl ketone was dissolved in 50 ml. of 2-propanol contained in an 8-inch test-tube. A drop of acetic acid was added, the tube was sealed in a flame and exposed to direct sunlight for two months. By this time, a few crystals had deposited on the walls of the tube. The tube was opened, the solution evaporated to a small volume in a steam-bath, cooled and the resulting crystals separated by filtration and washed with small amounts of 2-propanol. The product which weighed 3.6 g. (77%) melted at 123–125°. The melting point of a mixture of this substance with an authentic sample of phenyl-4-pyridylcarbinol[10] showed no depression.

NEW YORK, N. Y.

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[9] P. C. Teague, *ibid.*, **69**, 714 (1947).

[10] A. E. Chichibabin, *Ber.*, **37**, 1370 (1904).

[CONTRIBUTION FROM THE CHEMICAL LABORATORY, UNIVERSITY OF CALIFORNIA]

The Mechanism of the Reaction of Chloralquinaldine with Alkali[1]

BY WILLIAM G. DAUBEN AND C. WHEATON VAUGHAN, JR.

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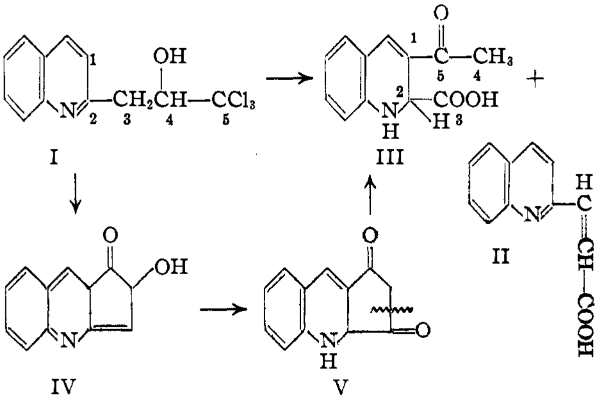
Chloralquinaldine (I) when treated with aqueous alcoholic alkali forms in addition to the expected quinolylacrylic acid (II) a rearrangement product, 3-acetyl-1,2-dihydroquinoline-2-carboxylic acid (III). This rearrangement has been investigated utilizing chloralquinaldine specifically labeled with carbon-14, and the mechanisms by which the reaction may proceed are discussed on the basis of the results obtained.

The reaction of chloralquinaldine (I) with aqueous alcoholic alkali forms two products, the expected quinolylacrylic acid (II) and a rearranged material[2] recently identified as 3-acetyl-1,2-dihydroquinoline-2-carboxylic acid[3] (III). It is evident that in the latter a deep-seated rearrangement has taken place, in which not only have two carbon atoms been transferred from the two to the three position of the heterocyclic nucleus, but also the 1,2-dihydro derivative has been formed with corresponding loss of resonance energy.

Woodward and Kornfeld[3] have postulated a mechanism sequence for this rearrangement. They viewed the reaction as involving the removal of an acidic hydrogen from the methylene group of the side chain to form a carbanion, the negative charge of which, available by resonance at the three position of the nucleus, might permit attack on the trichloromethyl group with the loss of chloride ion and formation of the cyclic intermediate IV. A series of steps involving dehydration, hydration



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[1] Presented before the Division of Organic Chemistry at the Atlantic City Meeting of the American Chemical Society, September, 1952.

[2] (a) A. Einhorn, *Ber.*, **19**, 904 (1886); *cf.* also A. Einhorn and P. Sherman, *Ann.*, **287**, 38 (1895); (b) W. Borsche and R. Manteuffel, *ibid.*, **526**, 22 (1936).

[3] R. B. Woodward and E. C. Kornfeld, THIS JOURNAL, **70**, 2508 (1948).