who used an ether solution of the hydrochloride of iodine monochloride. The introduction of chlorine into a suspension of iodine and cinnamic acid in water proved to be a convenient method for the preparation of α-iodo-β-hydroxyphenylpropionic acid.

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REDUCTION OF PYRIDINE HYDROCHLORIDE AND PYRIDONIUM SALTS BY MEANS OF HYDROGEN AND PLATINUM-OXIDE PLATINUM BLACK. XVIII[1]

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Although the catalytic reduction of pyridine and pyridine derivatives has been described in the literature,[3] no systematic work has been done which makes possible a prediction of satisfactory conditions for reducing compounds which contain the pyridine nucleus. A study has therefore been made of the reduction with hydrogen and platinum-oxide platinum black, of pyridine hydrochloride and pyridonium salts, quinoline and benzyl quinolonium chloride.

It has been found that pyridine alone in most solvents poisons platinum-oxide platinum black and no reduction takes place. On the other hand pyridine hydrochloride can be reduced readily. The selection of the proper solvent, however, is important. Absolute alcohol proved to be the best of those used, with glacial acetic acid second. Peculiarly enough, water in the alcohol inhibits the reduction very markedly and no satisfactory results were obtained using 95% ethyl alcohol or commercial methyl alcohol as a solvent. Absolute methyl alcohol could be used but it did not give such consistent results as absolute ethyl alcohol. Acetone and ethyl acetate do not dissolve the pyridine hydrochloride readily and, therefore, are not suitable.

As a standard run, 0.1 mole of pyridine hydrochloride in 150 cc. of solvent with 0.15 g. of platinum-oxide platinum black from c. p. chloroplatinic acid was used. The time required for the complete reduction was six to seven hours. In fact 0.15 g. of catalyst was the minimum which would allow complete reduction. Increase of the amount of catalyst to 0.3 g. lowered the reduction time to one hour and using 0.5 g. of catalyst lowered

[1] The last paper in this series was Adams and Marshall, THIS JOURNAL, **50**, 1970 (1928).

[2] This paper is a portion of a thesis submitted by T. S. Hamilton in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Chemistry at the University of Illinois.

[3] Skita and Brunner, *Ber.*, **49**, 1597 (1916); Darzens, *Compt. rend.*, **149**, 1001 (1909); Ipatiew, *Ber.*, **41**, 992 (1908).

the reduction time to thirty minutes. The yields were essentially quantitative in all instances.

Increasing the temperature increased the rate of reduction. With the standard run the reduction was carried out at room temperature. If the temperature was increased to 50°, the time for reduction dropped from six or seven hours to less than two hours.

Small amounts of ferrous salts and other mineral salts, which acted as promoters in the reduction of aldehydes, did not affect the reduction of pyridine hydrochloride. Oxygen and air, however, revivified a catalyst which had begun to be sluggish, and were employed in reductions which required a good many hours for completion.

Although all of these various conditions were not studied in the reduction of the pyridonium salts, a sufficient number of experiments was completed to show that, qualitatively, the pyridine hydrochloride and pyridonium salts were affected in the same way by changes in conditions. Using 0.1 mole of salt in 150 cc. of absolute alcohol and 0.15 g. of platinum-oxide platinum black, the following substances were reduced quantitatively to the corresponding hexahydro compounds in the following times: pyridine hydrochloride, six to seven hours; phenyl pyridonium chloride, two and one-quarter to two and one-half hours; *n*-butyl pyridonium chloride, one and one-half to two hours; ethyl pyridonium chloride, one to one and one-quarter hours; benzyl pyridonium chloride, one-half to three-quarters hour; carbo-ethoxymethyl pyridonium chloride, one-half to three-quarters hour; β-hydroxyethyl pyridonium chloride, three to three and one-quarter hours; γ-hydroxypropyl pyridonium chloride, one and three-quarters to two and one-half hours.

It is interesting that the pyridonium salts are in every instance more readily reduced than pyridine hydrochloride.

The quinoline and quinoline derivatives can be reduced to the tetrahydro compounds in exactly a similar manner. The reaction was carried out with quinoline hydrochloride and benzyl quinolonium chloride.

The general method should be of value in the reduction of alkaloids containing pyridine or quinoline nuclei.

Experimental

Catalyst.—The platinum-oxide platinum black was made by the method of Adams and Shriner[4] from C. P. chloroplatinic acid. Platinum oxide prepared by dissolving spent catalyst and reprecipitating without purification was not satisfactory for these reductions. The apparatus was that usually used and the procedure was exactly that which has been described before. Platinum oxide was reduced to platinum black in every instance in the presence of a solution of pyridine hydrochloride or pyridonium salt. The lag was approximately three minutes in most cases.

Preparations of Compounds to Be Reduced.—The pyridine used in the preparation of all compounds boiled between 116 and 118°.

[4] Adams and Shriner, THIS JOURNAL, **45**, 2171 (1923).

Pyridine hydrochloride was prepared by passing dry hydrogen chloride into dry pyridine dissolved in dry ether. It was necessary that the mixture be kept cold and that it be stirred constantly. The pyridine hydrochloride precipitated from the ethereal solution in a white, flocculent mass and settled quickly to the bottom of the flask. After the flask had increased to a weight indicating that approximately 85% of the pyridine had been changed to the hydrochloride, the salt was rapidly filtered into a Büchner funnel, taken up twice with absolute ether and the last traces of ether were removed by placing in a desiccator over calcium chloride and repeatedly evacuating. Because of the very deliquescent nature of the pyridine hydrochloride, it was stored in tightly stoppered bottles in a desiccator.

The ethyl and butyl chloride addition compounds of pyridine were made by mixing pyridine and the alkyl chloride in molecular proportions (usually the alkyl chloride in slight excess) and heating the mixture in a sealed tube on a steam-bath for several days or until the entire mixture had solidified. After opening the tube, the contents were washed out with as small as possible a quantity of warm absolute alcohol, the solution was cooled and the addition compound thrown out of the alcoholic solution by the addition of cold absolute ether. The ethyl and butyl chloride addition compounds were amber colored oils.

The phenyl pyridonium chloride was prepared by the method of Weitz, König and v. Wistinghausen.[5]

The benzyl chloride, chloroacetic acid, chloroacetic ester, ethylene and trimethylene chlorohydrin addition compounds were all prepared by the interaction of equimolecular quantities of pyridine and the compound to be added. The benzyl chloride, ethylene and trimethylene chlorohydrin derivatives were made by warming the mixture to start the reaction. It was sometimes necessary to cool the flask to prevent too vigorous boiling (especially true of the benzyl chloride compound). The chloroacetic acid and ethyl chloroacetate compounds were made merely by adding these compounds to pyridine and allowing the mixtures to stand in casseroles in a desiccator for a few days. The contents solidified after that time.

The addition compounds were isolated by crystallization from an ether–alcohol solution. Usually the compound was dissolved in a small amount of warm absolute alcohol, the solution cooled and the compound precipitated by the addition of cold ether, and by allowing to stand in a cold place. All compounds are very hygroscopic and the utmost care must be taken in order to obtain the salts in crystalline form, and to eliminate small quantities of water which inhibit the reductions.

Isolation of Products.—For the isolation of the reduced compounds the hydrogen was removed from the reduction bottle by suction and the bottle then shaken with air for ten to fifteen minutes in order to coagulate the platinum black, which was then filtered off. All reduced compounds were less hygroscopic and also less soluble in absolute alcohol than the unreduced. Piperidine hydrochloride may be quantitatively recovered from the alcoholic solution by concentration and crystallization. In all other cases, however, it was better to precipitate the reduced compound by adding ether until a precipitate just failed to appear and allowing to cool.

In the identification of all compounds, both those to be reduced and those reduced, the melting point of the hydrochloride was taken if possible (this was possible in but few cases), or a double salt, usually with platinum chloride, was made, or the free base was obtained by saturating with 40% sodium hydroxide and extracting with ether. In the latter case, after distillation of the ether, the boiling point of the free base was determined.

[5] Weitz, König and v. Wistinghausen, *Ber.*, **57**, 166 (1924).

The compounds prepared in this investigation are listed in Table I.

TABLE I

CONSTANTS OF AND REFERENCES TO UNREDUCED AND REDUCED COMPOUNDS

Compounds to be reduced	Ref.	Reduced products	Ref.	HCl salt, m. p., °C.	Base, b. p., [b]C.
$C_5H_5N \cdot HCl$	(1)	$C_5H_{11}N \cdot HCl$	(11)	236–237	...
$C_5H_5N \cdot C_2H_5Cl$	(2)	$C_5H_{11}NC_2H_5 \cdot HCl$	(12)	204[a]	127.6
$C_5H_5N \cdot C_4H_9Cl$	(3)	$C_5H_{11}NC_4H_9 \cdot HCl$	(13)	.....	175–177
$C_5H_5N \cdot C_6H_5Cl$	(4)	$C_5H_{11}NC_6H_5 \cdot HCl$	(14)	.....	258–260 (754 mm.)
$C_5H_5N \cdot C_6H_5CH_2Cl$	(5)	$C_5H_{11}NCH_2C_6H_5 \cdot HCl$	(15)	.....	247–251 (750 mm.)
$C_5H_5N \cdot ClCH_2COOH$	(6)	$C_5H_{11}NCH_2COOH \cdot HCl$	(16)	215–216	...
$C_5H_5N \cdot ClCH_2COOC_2H_5$	(7)	$C_5H_{11}NCH_2COOC_2H_5 \cdot HCl$	(17)	.....	209–212 (736 mm.)
$C_5H_5N \cdot ClCH_2CH_2OH$	(8)	$C_5H_{11}NClCH_2CH_2OH \cdot HCl$	(18)	.....	200–202 (742 mm.)
$C_5H_5N \cdot ClCH_2CH_2CH_2OH$		$C_5H_{11}NClCH_2CH_2CH_2OH \cdot HCl$	(19)	.....	194–196 (746 mm.)
$C_9H_7N \cdot HCl$	(9)	$C_9H_{13}N \cdot HCl$[b]	(20)	.....	...
$C_9H_7N \cdot C_6H_5CH_2Cl$	(10)	$C_9H_{13}NCH_2C_6H_5 \cdot HCl$[b]		.....	...

[a] Platinum chloride double salt.

[b] These compounds were not isolated. It was merely shown that the calculated amount of hydrogen was taken up for their formation.

(1) *Ann.*, **247,** 5 (1888); (2) *Monatsh.*, **15,** 180 (1894); (3) *Ann.*, **276,** 182 (1893); (4) *Ber.*, **57,** 166 (1924); (5) *J. prakt. Chem.*, [2] **41,** 345 (1890); (6) *ibid.*, **43,** 287 (1891); (7) *ibid.*, **43,** 271 (1891); (8) *Monatsh.*, **15,** 668 (1894); *Arch. Pharm.*, **240,** 78 (1902); (9) *Ber.*, **12,** 1322 (1879); (10) *Jahresber.*, **1882,** 1109; (11) *Ann.*, **247,** 55 (1888); (12) *Ber.*, **23,** 2570 (1890); *Ann. chim. phys.*, [3] **38,** 76 (1853); (13) *Ber.*, **40,** 3930 (1907); (14) *Ber.*, **21,** 2279 (1888); (15) *Ber.*, **32,** 74 (1899); *J. Chem. Soc.*, **99,** 1927 (1911); (16) *Ber.*, **32,** 728 (1899); (17) *Ber.*, **31,** 2840 (1898); (18) *Ber.*, **14,** 1877 (1881); (19) *Ber.*, **14,** 1876 (1881); (20) *Ber.*, **27,** 1479 (1893).

Summary

It has been shown that pyridine hydrochloride, quinoline hydrochloride or the corresponding pyridonium and quinolonium salts are readily reduced by means of hydrogen and platinum-oxide platinum black to the hexahydro compounds in the case of pyridine and tetrahydro compounds in the case of quinoline. The reductions under various conditions are described.

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