THE ATOMIC WEIGHT OF LEAD

$PbCl_2$, g.	Ag, g.	Ratio $PbCl_2$:2Ag	At. wt. Pb
0.54549	0.42318	1.28903	207.206
2.77993	2.15663	1.28902	207.204
1.17288	0.90990	1.28902	207.205
	Average	1.28902	207.205

The sample appears to be common lead and if so is one of the oldest to be examined.

Radium.—Attention is called to the fact that in the recent determination of the atomic weight of radium by Hönigschmid and Sachtleben (Sixth Report of this Committee) no correction is made for the effect of the temperature of radium salts on their weights. Allowance for this will presumably raise the atomic weight of radium by 0.01–0.02 unit.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, NEW YORK UNIVERSITY]

The Synthesis of Δ^3-Tetrahydropyridine

BY R. R. RENSHAW AND R. C. CONN[1,2]

In order to determine the physiological effect of introducing the double bond into the piperidine nucleus, we have prepared the Δ^3-tetrahydropyridine by the following series of reactions

$$\text{4-Hydroxypyridine} \xrightarrow[C_2H_5OH]{Na} \text{4-hydroxypiperidine} \xrightarrow{HBr} \text{4-bromopiperidine} \xrightarrow{NaOCH_3} \Delta^3\text{-tetrahydropyridine}$$

Koenigs and Neumann,[3] in describing the preparation of 4-iodo- and 4-bromopiperidines, state that these 4-halogenopiperidines split halogen acid, in alkaline solution, to give tetrahydropyridine. Apparently, this compound was not isolated nor characterized as no experimental details are given for the reaction. Paal and Hubaleck[4] believed that they obtained the gold salt of Δ^3-tetrahydropyridine when they submitted a C-sulfonic acid derivative of piperidine of unknown structure to a dry distillation with potassium hydroxide.

The only step in the series of reactions giving any difficulty was the reduction of the 4-hydroxypyridine. We were unable to obtain any reduction with Adams platinum oxide catalyst under varied experimental conditions, although Emmert[5] has patented a process for the reduction of 4-hydroxypyridine using a large amount of platinum black. The reduction was, therefore, carried out by means of sodium and alcohol according to Koenigs and Neumann,[6] and Emmert and Dorn.[7] The yield was only 30% although we were able to recover as much as 50% of the 4-hydroxypyridine.

The 4-halogenopiperidines do not readily split out hydrohalide. In an experiment in which 4-iodopiperidine was treated with alcoholic potassium hydroxide 4-hydroxypiperidine and unchanged 4-iodopiperidine were the only products isolated. This elimination of hydrohalide is best brought about by the use of sodium methylate or ethylate. The Δ^3-tetrahydropyridine was isolated as the hydrochloride and not as the free base because of the demonstrated ease of the polymerization of the latter.

Experimental Part

4-Hydroxypiperidine.—This substance was prepared by the sodium–alcohol reduction of 4-hydroxypyridine,[8] according to the directions of Koenigs and Neumann.[6] The yield was 30% with about 50% of the 4-hydroxypyridine recoverable.

4-Halogenopiperidine Hydrohalides.—4-Iodo- and 4-bromopiperidines were prepared by the method of Koenigs and Neumann.[3] The use of a somewhat larger (tenfold) excess of hydrobromic acid increased the yield of the bromo compound from 66 to 80%.

Alcoholic Potassium Hydroxide and 4-Iodopiperidine Hydriodide.—A solution of 1.6 g. (0.028 *M*) of potassium hydroxide in 18 cc. of absolute ethyl alcohol was added to 4.85 g. (0.014 *M*) of 4-iodopiperidine hydriodide and the suspension, after prolonged shaking, was allowed to stand overnight. Part of the alcohol was removed under reduced pressure at room temperature. Ether was added to precipitate the last traces of potassium iodide. The solution was filtered and the filtrate was saturated with dry hydrogen chloride. One and five-tenths grams of crystalline hydrochloride was obtained. Approximately 50% of this product dissolved readily in alcohol, the remainder being much more insoluble.

(1) This is the second paper constructed from the thesis presented by R. C. Conn, June, 1935, for the degree of Doctor of Philosophy at New York University.

(2) University Fellow in Chemistry.

(3) Koenigs and Neumann, *Ber.*, **48**, 961 (1915).

(4) Paal and Hubaleck, *ibid.*, **34**, 2761 (1901).

(5) H. Emmert, German Patent 292,456.

(6) Koenigs and Neumann, *Ber.*, **48**, 957 (1915).

(7) Emmert and Dorn, *ibid.*, **48**, 688 (1915).

(8) Koenigs and Greiner, *ibid.*, **64**, 1049 (1931); German Patent 536,891.

The more readily soluble fraction was identified as the hydrochloride of 4-hydroxypiperidine, m. p. 145–146°. (Koenigs and Neumann[6] give 146–148°.) The less readily soluble fraction was identified as the hydrochloride of 4-iodopiperidine, m. p. 171–172°. (Koenigs and Neumann[3] give 175–178°.)

Dry Potassium Hydroxide and 4-Bromopiperidine Hydrochloride.—The effect of a large excess of potassium hydroxide was tried by intimately mixing 2 g. (0.01 *M*) of 4-bromopiperidine hydrochloride and 5.6 g. (1.0 *M*) of dry, powdered potassium hydroxide in a 125-cc. distilling flask. The flask was cooled and 25 cc. of methyl alcohol added. The product was distilled with methyl alcohol into dilute hydrochloric acid by gentle warming under reduced pressure. The acid was then evaporated to dryness *in vacuo* over phosphorus pentoxide. One and three-tenths grams of hydrochloride was obtained. Fractional crystallization from alcohol–ether gave two fractions. The first consisted of 0.1 g. of 4-bromopiperidine hydrochloride, m. p. 190°. (Koenigs and Neumann[3] give 188–189°.) The second and more readily soluble fraction consisted of 1.1 g. (85%) of 4-hydroxypiperidine hydrochloride, m. p. 146–148°.

Anal. Calcd. for $C_5H_{12}ONCl$: Cl, 25.56. Found: Cl, 25.61.

Platinum salt, m. p. 186–187° (dec.) (the literature[3] gives 184–187° with decomposition).

Δ^3-Tetrahydropyridine Hydrochloride. Procedure I.—A solution of 2.3 g. (0.1 *M*) of sodium in absolute methyl alcohol was added to 2.45 g. (0.01 *M*) of 4-bromopiperidine hydrobromide in 50 cc. of the same solvent. After warming at 50–60° in a 250-cc. distilling flask for two hours, the methyl alcohol was distilled off under reduced pressure into dilute hydrochloric acid. Seven-tenths of a gram of hydrochloride was obtained by evaporating the solution under reduced pressure. By fractionally precipitating the alcoholic solution of the product by ether, 0.5 g. of crystalline hydrochloride melting at 188–189° (corr.) and 0.1 g. of amorphous material melting from 100–110° were obtained.

Procedure II.—Two and five-tenths grams (0.01 *M*) of 4-bromopiperidine hydrobromide and 6.8 g. (0.1 *M*) of dry sodium ethoxide were mixed intimately in a 125-cc. distilling flask and 25 cc. of absolute ethyl alcohol was added with shaking. After warming at 50–60° for one hour the alcohol was removed under reduced pressure and the volatile base was isolated as before. From this solution 0.6 g. of a hydrochloride identical with that obtained in Procedure I was isolated.

Anal. Calcd. for $C_5H_{10}NCl$: N, 11.71; Cl, 29.67. Found: N, 11.62; Cl, 29.30, 29.35.

Gold Salt.—This product was obtained from dilute hydrochloric acid by evaporating *in vacuo* at room temperature. The tendency of solutions of the gold salt, mentioned by Paal and Hubaleck[4] as characteristic of the chloroaurate of their tetrahydropyridine, to deposit metallic gold on standing was observed. The first crystals to appear were contaminated with traces of metallic gold and were removed by filtration. Further concentration gave yellow plates, m. p. 141–142° (dec.).

Anal. Calcd. for $C_5H_{10}NCl_4Au$: Au, 46.59. Found: Au, 46.55, 46.56.

Platinum Salt.—This product was obtained from alcoholic hydrochloric acid by concentration *in vacuo* as yellow plates, m. p. 187–188° (dec.) (corr.).

Anal. Calcd. for $C_{10}H_{20}N_2Cl_6Pt$: Pt, 33.90. Found: Pt, 33.47, 33.62.

Evaporating an alcoholic solution of the hydrochloride of the tetrahydropyridine to dryness on a steam-bath, gave an amorphous hydrochloride, m. p. 70–80°. It gave, however, the same analysis and a platinum salt of the same melting point as was obtained from the hydrochloride before evaporation. It possibly was the hydrochloride of the polymerized base.

4-Methoxypiperidine Hydrochloride.—This product was obtained from a run in which a larger quantity of 4-bromopiperidine hydrobromide was heated with sodium methylate. After distilling off the alcohol under reduced pressure, the residue was extracted with ether and dry hydrogen chloride then passed into the ether extract. The precipitate consisted of the hydrochloride of 4-bromopiperidine and a second fraction, more readily soluble in alcohol, which analyzed as the hydrochloride of 4-methoxypiperidine. The yield was 25%; m. p. 137.5–139.5° (corr.).

Anal. Calcd. for $C_6H_{14}ONCl$: Cl, 23.39. Found: Cl, 23.32.

Platinum Salt.—Yellow plates from alcoholic hydrochloric acid, m. p. 178–178.5° (dec.) (corr.).

Anal. Calcd. for $C_{12}H_{28}O_2N_2Cl_6Pt$: Pt, 30.49. Found: Pt, 30.16, 30.21.

Addition of Bromine to the Tetrahydropyridine.—A solution of 0.12 g. of the hydrochloride of the tetrahydropyridine in 10 cc. of ethyl alcohol was allowed to stand with a slight excess of bromine for thirty minutes, and then was warmed very gently on a water-bath for a few minutes to complete the reaction. The alcohol was evaporated to dryness under reduced pressure and the crude residue recrystallized from hot alcohol in which it was only sparingly soluble. The yield was 0.26 g., m. p. 193° (dec.) (corr.).

Anal. Calcd. for $C_5H_9NClBr_2$: Cl, 12.74. Found: Cl, 12.60.

Platinum Salt.—This salt was obtained as well-formed crystals from an aqueous solution of the components, after standing for several hours; m. p. 216–217° (dec.).

Anal. Calcd. for $C_{12}H_{20}N_2Cl_6Br_4Pt$: Pt, 21.73. Found: Pt, 21.75, 21.78.

Dimethyl-Δ^3-tetrahydropyridinium Iodide.—Five and two-tenths grams of 4-bromopiperidine hydrobromide and 16 g. of dry sodium ethoxide were mixed and a total of 200 cc. of absolute ethyl alcohol was added in 25- to 50-cc. portions. The alcohol was removed under reduced pressure and was collected in a trap cooled with Dry-Ice. Excess methyl iodide and powdered barium hydroxide were added to the distillate. After standing for a week at room temperature in a tightly stoppered flask, the solution was filtered and barium chloride was precipitated by the addition of dry hydrogen chloride. The barium chloride was filtered and the filtrate was concentrated by evaporation under reduced pressure. Ethyl acetate was added to complete the precipitation. The yield was 3.6

g. or 71%. Recrystallization by concentration of its alcoholic solution *in vacuo*, at room temperature, gave white plates, m. p. 274–275° (dec.) (corr.). It was only sparingly soluble in alcohol.

Anal. Calcd. for $C_7H_{14}NI$: I, 53.10. Found: I, 53.20, 53.14.

To prove the identity of this dimethyl derivative, 0.25 g. dissolved in alcohol was shaken with 0.05 g. of Adams platinum oxide catalyst under hydrogen at atmospheric pressure. Reduction proceeded rapidly and the calculated quantity of hydrogen was absorbed. The solution was concentrated, yielding 0.2 g. of prismatic crystals; m. p. 332–333° (dec.). This was identical with an authentic sample of dimethylpiperidinium iodide, m. p. 334° (dec.), prepared from piperidine and methyl iodide.[9]

Anal. Calcd. for $C_7H_{16}NI$: I, 52.65. Found: I, 52.30, 52.32.

Summary

1. Δ^3-Tetrahydropyridine has been prepared and isolated as the hydrochloride.

2. Dimethyl-Δ^3-tetrahydropyridinium iodide has been prepared for physiological testing.

(9) Wedekind and Oechslen, *Ber.*, **35**, 1076 (1902).

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[CONTRIBUTION FROM THE RESEARCH LABORATORIES OF THE UNIVERSAL OIL PRODUCTS COMPANY]

Action of Aluminum Chloride on Cyclohexylbenzene

BY B. B. CORSON AND V. N. IPATIEFF

Bodroux[1] obtained a compound melting at 169–170° as by-product in the alkylation of benzene with cyclohexene in the presence of aluminum chloride. He assumed that it was 1,2-diphenylcyclohexane and that it resulted from the dehydrogenation and rearrangement of dicyclohexylbenzene. The object of our study was to discover the source of this by-product and to determine its structure.

Corson and Ipatieff[2] obtained the same compound in the dealkylation of polycyclohexylbenzenes, and in the present work it also was obtained by the action of aluminum chloride upon monocyclohexylbenzene. Bodroux's suggested mechanism is probably incorrect. The more likely source of the diphenylcyclohexane is monocyclohexylbenzene rather than dicyclohexylbenzene.

Bodroux's evidence for the structure of the 169–170° compound was carbon–hydrogen analysis and melting point. Its melting point was the same as that of a compound described by Kursanoff[3] as 1,2-diphenylcyclohexane, which he obtained from the reaction between 1,2-dichlorocyclohexane and benzene in the presence of aluminum chloride.

We prepared Kursanoff's compound by the interaction of 1,2-dibromocyclohexane with benzene in the presence of aluminum chloride. Mixed melting point showed that it was identical with the product previously obtained[2] in the dealkylation of polycyclohexylbenzenes and also with that obtained in the present work by the action of aluminum chloride on monocyclohexylbenzene.

However, this 169–170° compound is 1,4-disubstituted and not 1,2- as assumed by Kursanoff and Bodroux. We confirm the recent findings of Nenitzescu and Curcaneanu[4] on this point. This rearrangement illustrates the well-known fact that structure cannot be based upon reactions which are catalyzed by aluminum chloride. Our evidence for the 1,4-structure of the 169–170° compound is that it hydrogenates to give a mixture of the two isomeric 1,4-dicyclohexylcyclohexanes.[5]

Cyclohexylbenzene yields a number of products when it is heated at 80–85° with aluminum chloride. The main products—dicyclohexylbenzene, benzene, diphenylcyclohexane, and cyclohexane—indicate the following reactions, in which both phenyl and cyclohexyl groups act as hydrogen donors.[6]

$$2C_6H_{11}C_6H_5 \longrightarrow C_6H_{11}C_6H_4C_6H_{11} + C_6H_6$$
$$2C_6H_{11}C_6H_5 \longrightarrow C_6H_5C_6H_{10}C_6H_5 + C_6H_{12}$$

The lowest boiling fraction contained, besides benzene and cyclohexane, also some hexane (from the opening and hydrogenation of cyclohexane) and probably some methylcyclopentane (from the isomerization of cyclohexane). The second fraction was unchanged cyclohexylbenzene.

Two solids were isolated from the third fraction, 1,4-diphenylcyclohexane (m. p. 169–170°) and 1,4-

(1) Bodroux, *Ann. chim.*, [10] **11**, 511 (1929).

(2) Corson and Ipatieff, THIS JOURNAL, **59**, 646 (1937).

(3) Kursanoff, *Ann.*, **318**, 309 (1901).

(4) Nenitzescu and Curcaneanu, *Ber.*, **70**, 346 (1937).

(5) (a) Von Braun, Irmisch and Nelles, *ibid.*, **66**, 1471 (1933); (b) Corson and Ipatieff, THIS JOURNAL, **59**, 646 (1937).

(6) In a recently described cleavage reaction [Ipatieff and Pines, THIS JOURNAL, **59**, 56 (1937)] only the cyclohexyl group functioned as hydrogen donor.