−3 was used in the case of allylbenzene which contains one ring and a decrement of −6 in the three compounds containing both an aromatic and a polymethylene ring. The use of this decrement is, we believe, justified by the fact that a ring carbon atom attached to a side chain acts as a heaping center.[19] We have, therefore, in effect the equivalent of a —CHR_2 group.[18]

The greatest deviation (0.9%) of the observed parachor from the calculated is found in cyclobutylphenylmethane, where the unknown effect of the strain of a four-membered ring is a factor.

(19) Kaufmann, *loc. cit.*, pp. 93, 97.

Summary

1. In condensation reactions with benzene in the presence of aluminum chloride the cycloalkylcarbinols show a progressive increase in activity as the number of carbon atoms of the ring is reduced from six to four.

2. Physical constants of allylbenzene, cyclobutylphenylmethane, cyclopentylphenylmethane are recorded and discussed.

EAST LANSING, MICH. RECEIVED JULY 14, 1934

[CONTRIBUTION FROM THE PATHOLOGICAL DIVISION, BUREAU OF ANIMAL INDUSTRY]

Lupine Studies. VIII. The Alkaloids of Lupinus Palmeri, S. Wats.

BY JAMES FITTON COUCH

Lupinus palmeri, S. Wats. is a perennial species of lupine found in certain parts of Utah and neighboring states. Its systematic position has been doubtful, some botanists referring it to the species caudatus, others naming some specimens of *L. caudatus*, *L. palmeri*. Chemical examination of authentic specimens of these two species demonstrates that their alkaloidal constituents are quite distinct and do not vary in different years.

The study of *L. palmeri* has resulted in the isolation of three lupine alkaloids, two of which are new, lupinine, tetralupine[1] and pentalupine. Sparteine, which has hitherto always accompanied lupinine in this genus, was found absent, which fact, coupled with the discovery of sparteine and absence of lupinine in *L. barbiger*,[2] demonstrates that there is no biochemical necessity for their occurring together. Tetralupine is of interest because it is isomeric with lupinine and isolupinine[3] and is found in nature while isolupinine is not naturally occurring. Whether it is the allolupinine postulated by Winterfeld and Holschneider[4] remains to be determined.

Experimental Part

Collection of Plant Material.—The plant used in this study was collected by my colleague, Mr. A. B. Clawson, on July 9, and on August 7 and 8, 1931, at a point 10 miles south of Cove Fort, Utah. Most of the plants were then in bloom, a few had developed pods and a few had not yet bloomed. The material was identified as *L. palmeri* by Mr. W. W. Eggleston of the Bureau of Plant Industry. The material was air dried, bagged and shipped to this Laboratory, where it was ground to a coarse powder.

Moisture.—The ground material contained 8.94% of matter volatile at 110°.

Extraction of the Alkaloids.—60.9 kg. of ground plant was extracted with alcohol. The solvent was distilled and the residual extract was boiled with successive portions of water until all soluble matter was removed.

The concentrated water solutions were treated with an excess of a mixture of neutral and basic lead acetates, filtered and freed from excess of lead with sulfuric acid. The filtrate was concentrated, made alkaline with sodium hydroxide, and shaken out with chloroform. The solvent was distilled from the separated solution and left the crude alkaloids in the form of a reddish sirup that weighed 2222 g. This sirup contained nearly 25% of its weight of chloroform that could not be distilled off at water-bath temperature and ordinary pressure. Much of it might be removed by heating under reduced pressure but some of the alkaloids were volatile under these conditions and would have been lost. The chloroform was expelled by adding enough methanol to the mixture to form the azeotropic mixture with the chloroform which boils at 53.6° and distilling the solution. The last traces of chloroform could be removed by repeating the process twice. By this means 1668 g. of crude alkaloid corresponding to 3.00% of the dry plant material was obtained. The mixture gave a very faint modified Grant test.[5]

Isolation of Lupinine

A portion of 310 g. of the crude alkaloid mixture was poured into a flask and warmed under 20 mm. pressure to remove volatile matter. When the residual solvent (traces only) had been removed, the pressure sank to 6 mm. and a crystalline sublimate formed on the walls of the flask.

(1) Nomenclature, *cf.* THIS JOURNAL, **56**, 155 (1934).
(2) Couch, *ibid.*, **54**, 1691 (1932).
(3) Steinsiek, Dissertation, Marburg, 1928.
(4) Winterfeld and Holschneider, *Ber.*, **64**, 137–150 (1931).
(5) Couch, *Am. J. Pharm.*, **97**, 37 (1925).

The heating was discontinued and the specimen was allowed to cool. On the following morning it was found to have deposited an abundance of long, stubby needles, some 3 cm. in length. Recrystallized from acetone the substance formed thick rhombic prisms of m. p. 68–69°.

A large portion of the alkaloid (200 g.) was repeatedly distilled *in vacuo*, until there was obtained a colorless substance that yielded a colorless fluid on melting and solidified rapidly in the receiver. Distilled from a 1-liter Claisen flask with the addition of ground glass to prevent bumping and at a pressure of 4 mm., the greater part of the alkaloid passed over between 160 and 163° (corr.), m. p. 68–69°, b. p. (754.5 mm.) 269–270° (Anschütz thermometer, mercury wholly in vapor). Willstätter and Fourneau give 255–257°[6,7] and Schulz[8] gives 269–270° for the boiling point of lupinine at 760 mm. pressure. Mixed with an authentic specimen of lupinine of m. p. 68–69° prepared from *Lupinus luteus* the melting point was not depressed.

Anal. Calcd. for $C_{10}H_{19}ON$: C, 70.92; H, 11.29; N, 8.24. Found: C, 70.91, 71.08, 71.12; H, 11.34, 11.28, 11.30; N,[9] 8.11, 8.22, 8.19. In water, $[\alpha]_D^{26}$ −25.93°, $c = 3.1832, l = 1, a = 0.8254°$. In alcohol, $[\alpha]_D^{28}$ −20.91°, $c = 9.5412, l = 1, a = 1.977°$.[10]

Salts of Lupinine.—Hydrochloride, m. p. 207–209°, Cl calcd. 17.20; found 17.10, 17.06. Hydriodide, m. p. 140–141°, calcd. I, 40.27; N, 4.44; C, 38.08; H, 7.01; found I, 40.56, 40.58; N, 4.48; C, 38.17; H, 6.96. Gold chloride, m. p. 211–213°, Au calcd. 38.72; found 38.63. Platinum chloride, m. p. 166–166.5°, calcd. Pt 25.73; H_2O, 1.19; found Pt 25.81; H_2O, 0.75. Methiodide, m. p. 295–296°. Calcd. I 40.79; N, 4.50; found I 40.79, 40.65; N, 4.62; in water $[\alpha]_D^{30}$ 10.08°, $c = 13.584, l = 1, a = 1.37°$.[11] Methochloride, m. p. 212–213°. Cl calcd. 16.16; found 16.50. Picrate, prepared by Höllwig's method[12] m. p. 136–137°. Prepared by recrystallization from watery acetone, m. p. 196–197°. Phenyl urethan, m. p. 98–99°. *d*-Camphorsulfonate, m. p. 181–182°. Calcd. N 3.49; S, 7.97; found N 3.46; S 7.98.

Search for Sparteine

Before the year 1931 when Orechoff and Menschikoff[13] reported the presence of lupinine in *Anabasis aphylla*, the base had been found in one plant only, *Lupinus luteus* including the mutational form, called *L. niger*, and there it had been associated with sparteine. It was necessary to determine whether sparteine is also present in *L. palmeri*. A 5-g. test portion of the fluid alkaloid mixture from which lupinine had crystallized was distilled under reduced pressure; 3 g. of yellowish oil was obtained up to 160° at 6 mm. This oil gave a very faint modified Grant test, did not precipitate with mercuric chloride in water or alcohol, and gave no precipitate with picric acid in alcohol. Sparteine was, therefore, absent and this conclusion was confirmed by subsequently obtained evidence.

Isolation of a New Lupine Alkaloid, Tetralupine, Isomeric with Lupinine.—The mother liquor from the lupinine, 175 g., was examined for the presence of other alkaloids. The result of a number of experiments made it evident that it contained, in addition to lupinine, at least two other alkaloids difficult to separate in a pure condition.

The remainder of the original alkaloids freed from chloroform was extracted with petroleum ether. The solution was cooled and filtered from the crystallized lupinine. The dissolved material, recovered by distilling off the solvent, was fractionated *in vacuo*. The lower boiling fractions contained lupinine and a new base, tetralupine; the highest boiling fractions consisted of a second new base, pentalupine. Much of the lupinine was frozen out of the united low-boiling fractions and the fluid portion was then converted into the *d*-camphorsulfonates in acetone. The tetralupine salt crystallized first and when recrystallized from acetone several times melted constantly at 164–165°. Mixed with lupinine *d*-camphorsulfonate (m. p. 181–182°) the mixture melted between 150 and 160°.

The crystals were dissolved in water, made alkaline with sodium hydroxide, and the liberated base shaken out with chloroform. On distilling the solvent and removing the adherent solvent with methanol as already described, the new base was left in the form of a light yellow oil of n_D^{26} 1.5128 and density 25/4 1.0194. After standing for two weeks in the laboratory the oil began to crystallize and within a week the whole had solidified. The mass was broken up and washed with petroleum ether in which it was very insoluble. When dried it melted at 76–78.5°. Recrystallized from a mixture of 10% chloroform and 90% petroleum ether the alkaloid formed spearhead crystals of m. p. 81–83°. The alkaloid is soluble in water and the usual organic solvents except petroleum ether. It is, however, very soluble in petroleum ether when lupinine is also present.

Anal. Calcd. for $C_{10}H_{19}ON$: C, 70.92; H, 11.29; N, 8.24. Found: C, 70.84, 70.87; H, 11.11, 11.38; N, 8.32, 8.29, 8.38; $[\alpha]_D^{26}$ 4.63, $c = 7.7124, l = 2, a = 0.7317°$.

Tetralupine *d*-Camphorsulfonate.—The salt prepared as already described was recrystallized from acetone several times until the melting point was constant at 164–165°. The salt contained crystal water which could not be estimated accurately on account of decomposition.

Anal. Calcd. for $C_{10}H_{19}ON \cdot C_{10}H_{16}O_4S \cdot H_2O$: N, 3.33 S, 7.62. Found: N, 3.24, 3.27; S, 7.68. In water $[\alpha]_D^{30}$ 18.18°, $c = 3.3572, l = 1, a = 0.61°$.

Comparison of Tetralupine with Isolupinine

It appeared possible that tetralupine might be identical with isolupinine, a base discovered by Steinsiek[3] and confirmed by Krieg.[14] A specimen of the latter was therefore prepared by the method of Steinsiek, which consists in warming lupinine with metallic sodium in benzene for several hours. The isomeric base melted at 77–79°.

(6) Willstätter and Fourneau, *Ber.*, **35**, 1910 (1902).

(7) Willstätter and Fourneau, *Arch. Pharm.*, **240**, 335 (1902).

(8) Schulz, *Landw. Jahrbüch.*, **8**, 37-64 (1879).

(9) All of the nitrogen determinations reported in this paper were made by the cartridge method, THIS JOURNAL, **55**, 852 (1933).

(10) (a) Schmidt and Gerhard, *Arch. Pharm.*, **235**, 342 (1897), give −19° in water at 17° ($c = 3.4878$), while (b) Schmidt and Berend, *ibid.*, **235**, 269 (1897), reported three values obtained from aqueous solutions of varying concentration, at 18°, *viz.*, −26, −23.7, −20°, $c = 3.16, 1.58$ and 0.95%, respectively.

(11) Steinsiek, Dissertation, Marburg, 1928, gives $[\alpha]_D$ 9.5°, c = 4% in water.

(12) Höllwig, Dissertation, Marburg, 1927.

(13) Orechoff and Menschikoff, *Ber.*, **64**, 266–274 (1931).

(14) Krieg, Dissertation, Marburg, 1928, p. 29.

Krieg gives 76–78°. Mixed with tetralupine the mixture began to melt at 61° and was completely fluid at 79°. Other differences between the two compounds are: isolupinine is more strongly dextrorotatory than tetralupine, $[\alpha]_D^{15}$ 38.17°[14] and readily forms double compounds with gold and platinum chlorides that are insoluble in alcohol. The corresponding compounds of tetralupine are so soluble in water and alcohol that they cannot be isolated.

Isolation of a New Alkaloid, Pentalupine

The highest boiling fraction was a deep yellow oil with a strong green fluorescence, n_D^{25} 1.5252; in alcohol, $[\alpha]_D^{29}$ −3.197°. Its melting range at 2 mm. was 170–210°. To purify it the fraction was converted into hydrochloride but no crystalline compound could be isolated. The alkaloid was regenerated from this salt and was warmed under reduced pressure to remove solvent. The substance was then fractionated in vacuum. The first portions of distillate were discarded and the middle fraction, boiling 175 to 182° was taken. Ten grams of straw yellow oil with a strong greenish fluorescence was obtained, $n_D^{29.5}$ 1.5155. No crystalline compounds have been obtained from this substance.

Anal. Calcd. for $C_{16}H_{30}ON_2$: C, 72.12; H, 11.34; N, 10.52. Found: C, 72.07, 72.17; H, 11.49, 11.32; N, 10.47, 10.46, 10.49.

Summary

Lupinus palmeri, S. Wats. contains three alkaloids: lupinine, $C_{10}H_{19}ON$, previously found in *L. lutieus and in Anabasis aphylla;* tetralupine, a new alkaloid isomeric with lupinine and not identical with isolupinine; and pentalupine, provisionally given the formula $C_{16}H_{30}ON_2$, also a new alkaloid. Sparteine does not occur in this plant.

WASHINGTON, D. C. RECEIVED JULY 21, 1934

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF BROWN UNIVERSITY]

The Structure of Metal Ketyls. II. The Dissociation of Alkali Metal Pinacolates to Metal Ketyls in Liquid Ammonia Solution

BY CHARLES BUSHNELL WOOSTER

Bachmann[1] has shown by isolating the pinacol formed on rapid hydrolysis with excess acetic acid, that the sodium derivatives of ketones, the so-called metal ketyls, *as prepared in ether by previous investigators,* are not monomolecular free radicals but sodium pinacolates or equilibrium mixtures of sodium-ketyl and sodium pinacolate in which the equilibrium is almost entirely in favor of the sodium pinacolate. However, a similar investigation of the solutions obtained from benzophenone and one equivalent of sodium in *liquid ammonia* leads to the conclusion that relatively high concentrations of the monomolecular ketyl are present under these conditions. Thus in a solution which is approximately 0.15 *N* (with respect to the pinacolate) the pinacolate is about 85% dissociated into the ketyl in accordance with Equation 1.

$$\begin{matrix}(C_6H_5)_2CONa\\ |\\ (C_6H_5)_2CONa\end{matrix} \rightleftharpoons 2(C_6H_5)_2CONa \qquad (1)$$

In addition to the direct influence of the solvent upon the dissociation equilibrium, two other clearly understandable reasons for the striking difference between the results of Bachmann and those of the present investigation may be pointed out. First, these sodium compounds are only moderately soluble in ether, and in Bachmann's experiments a large amount of the pinacolate was present as a precipitate. Thus his results are not an accurate measure of the state of the dissociation equilibrium *in solution.* Second, the pinacolate undoubtedly undergoes electrolytic dissociation in liquid ammonia[2] and the electrostatic repulsion between the two negative charges may well play a part in promoting dissociation of the pinacolate anion into ketyl anions.[3]

$$\begin{matrix}(C_6H_5)_2CO^-\\ |\\ (C_6H_5)_2CO^-\end{matrix} \rightleftharpoons 2(C_6H_5)_2CO^- \qquad (2)$$

As it is impossible to attribute the conductance values obtained by Kraus and Bien entirely to simple electrolytic dissociation of the small amount of pinacolate present, without ascribing ridiculously high values to the limiting equivalent conductance of the pinacolate anion, it is evident that the simple ketyl anion, R_2CO^-, actually exists in liquid ammonia. This anion is an interesting and unusual type of stable complex because it contains both an *odd* and an *extra* electron. Modern electronic theories of valence recognize,

(1) Bachmann, THIS JOURNAL, **55**, 1179 (1933).

(2) Kraus and Bien, *ibid.*, **55**, 3609 (1933).

(3) Electrolytic dissociation of the pinacolate in ether solution is, of course, not excluded, but this ionization would be much greater in liquid ammonia in accordance with the well-known differences in the suitability of these two liquids as electrolytic solvents.