

(ϵ 7100) and 245 (5800); ir (KBr) 6.28, 6.55, 6.69 μ ; ^1H nmr (acetone- d_6) τ 6.53 (t, $J_{\text{NH}} = 0.5$ Hz); ^{19}F nmr (acetone), CCl_3F std, δ 57.2 ppm (q, $J = 2.1$ Hz, 3 F), 60.9 (q, $J = 2.1$ Hz, 3 F), and 64.2 (s, 3 F). An analytical sample was prepared by a second recrystallization from alcohol-ether.

Anal. Calcd for $\text{C}_{11}\text{H}_{12}\text{F}_3\text{N}_2$: C, 34.29; H, 3.14; F, 44.39; N, 18.18. Found: C, 34.41; H, 3.30; F, 44.14; N, 17.84.

3-Methyl-2,4,6-tris(trifluoromethyl)-3,6a-dihydro-1,3,5,6a-tetrazapentalene (11).—A 3% solution of diazomethane in ether was added dropwise to a solution of 1.0 g of 10 in 5 ml of ether until no further evolution of nitrogen was evident. The solution was evaporated to dryness. The ^1H nmr spectrum of the crude product showed two signals at 5.65 (7%) and 6.08 (93%). Two recrystallizations from pentane gave 0.75 g of 11 as long needles: mp 43–45.5°; uv (ethanol) λ_{max} 266 m μ (ϵ 3800), 226 (5500); ir (KBr) 6.12, 6.42, 6.49, and 6.63 μ ; ^1H nmr (acetone- d_6) τ 6.08 (poorly resolved multiplet, probably two overlapping quartets, $J_{\text{HF}} \sim 0.6$ Hz); ^{19}F nmr (acetone), CCl_3F std, δ 57.5 ppm (m, probably two overlapping quartets with $J_{\text{FF}} = 1.0$ and $J_{\text{FH}} = 0.6$ Hz), 62.2 (q, $J = 1.0$ Hz), and 64.1 (q, $J = 0.6$ Hz). An analytical sample was prepared by a third recrystallization from pentane.

Anal. Calcd for $\text{C}_9\text{H}_3\text{F}_3\text{N}_4$: C, 29.46; H, 0.93; F, 52.43; N, 17.18. Found: C, 29.26; H, 0.87; F, 52.48; N, 16.90.

Registry No.—10a, 25894-19-3; tetramethylammonium salt of 10a, 25894-20-6; 11, 25894-21-7.

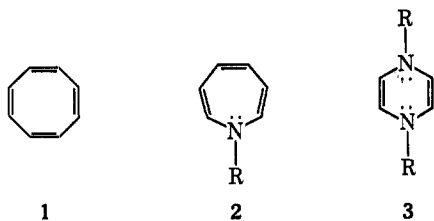
Structures of Alleged 1,4-Dihydropyrazines

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Received April 16, 1970

The 1,4-dihydropyrazine ring system is an interesting conjugated cyclic structure containing 8 π electrons. It is electronically analogous to cyclooctatetraene and 1*H*-azepine, both of which have in recent years displayed some fascinating chemistry.¹ Since the 1,4-



dihydropyrazine ring system is generally thought to be a known structure² and has been used to demonstrate the nonaromatic character of 8- π -electron compounds³ we are prompted to report the following results. We have repeated the work in the most frequently quoted reference⁴ and find the original structural assignments to be in error.

Mason⁴ has reported that the base-catalyzed cyclo-

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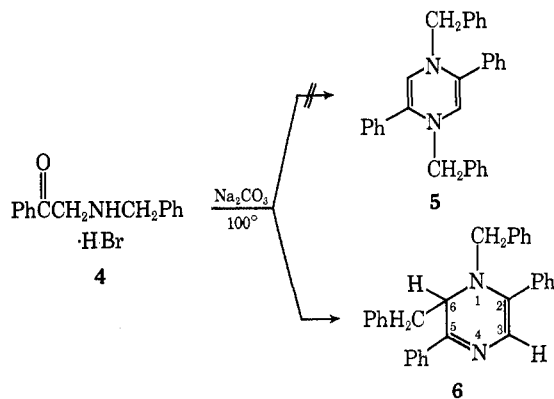
(1) For leading references, see (a) L. A. Paquette, D. E. Kuhla, J. H. Barrett, and L. M. Leichter, *J. Org. Chem.*, **34**, 2888 (1969); (b) G. Schroder, "Cyclooctatetraene," Verlag Chemie, Weinheim/Bergstr., Germany, 1956.

(2) Y. T. Pratt and R. C. Elderfield, *Heterocycl. Compounds*, **6**, 414 (1957).

(3) A. Streitwieser, "Molecular Orbital Theory for Organic Chemists," Wiley, New York, N. Y., 1961, p 276.

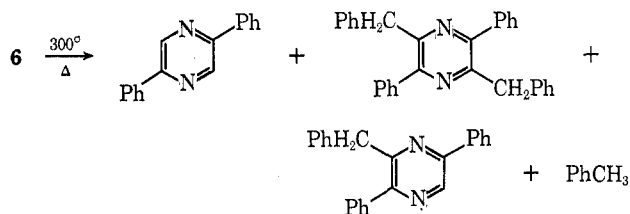
(4) A. T. Mason and G. R. Winder, *J. Chem. Soc.*, **63**, 1355 (1893).

dehydration of *N*-phenacylbenzylamine hydrobromide (4) gives 1,4-dihydropyrazine (5). The nmr spectrum



of the product from this reaction showed in the non-aromatic region two doublets at τ 5.17 and 5.30 (1 H, $J = 5.0$ Hz), a quartet (AB), centered at 6.15 (2 H, $J = 15.0$ Hz), and a complex multiplet at 6.83–7.62 (2 H). This spectrum is clearly inconsistent with 5. However, structure 6 is in agreement with the available data. The two proton multiplet at τ 6.83–7.62 and the one proton doublets at 5.17 and 5.30 are assigned to the AB and the X portions of an ABX spectrum. These absorptions represent the benzyl hydrogens of the benzyl group at C₆ and methine hydrogen at C₆. Irradiation of the τ 6.83–7.62 multiplet caused the doublets at 5.17 and 5.30 to collapse into a singlet confirming the coupling between these two groups of hydrogens. The AB quartet centered at τ 6.15 is assigned to the benzyl hydrogens adjacent to the nitrogen atom. The nonequivalence of the hydrogens on both benzyl substituents is attributable to the presence of the asymmetric carbon atom (C₆) in dihydropyrazine 6. Similar effects have been observed in related systems.⁵

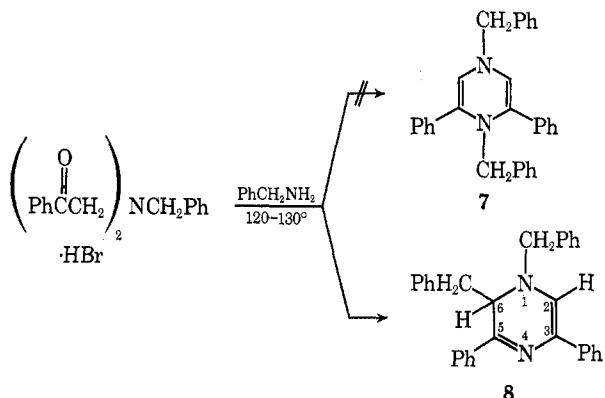
Pyrolysis of 6 gave a mixture of pyrazines which further supports the postulated dihydropyrazine structure for 6.



The reaction of diphenacylbenzylamine hydrobromide with benzylamine is also reported to give the 1,4-dihydropyrazine ring system,⁴ 7. The nmr spectrum of the reaction product, which is similar to 6, is inconsistent with structure 7. The methine hydrogen at C₆ occurs as two doublets (τ 5.17 and 5.32, $J = 5$ Hz) further split by the vinyl hydrogen (τ 3.42, d, $J = 1$ Hz) at C₂. The benzyl hydrogens of the benzyl group (τ 6.87–7.70) at C₆ occur as a complex multiplet. Irradiation of the τ 6.87–7.70 multiplet caused the doublets at τ 5.17–5.32 to collapse into a singlet thus confirming the coupling between these groups of hydrogens. The benzyl hydrogens adjacent to the nitrogen occur as an AB quartet centered at τ 6.32 ($J = 15$ Hz).

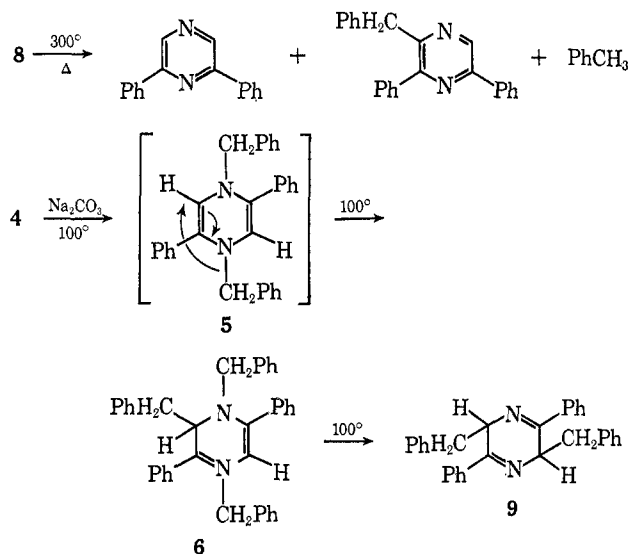
(5) J. C. Randall, J. J. McLeskey, III, P. Smith, and M. E. Hobbs, *J. Amer. Chem. Soc.*, **86**, 3229 (1964).

An attempt was made to isolate the 1,4-dihydropyrazine **7** by carrying out the reaction at lower tempera-



ture in refluxing benzene and azeotropically removing the water produced. Only the dihydropyrazine **8** could be isolated.

Pyrolysis of **8** gave a mixture of 3,5-diphenylpyrazine and 3,5-diphenyl-2-benzylpyrazine.



The formation of both **6** and **8** can be rationalized as initially proceeding through the 1,4-dihydropyrazine which undergoes a 1,3 shift of a *N*-benzyl substituent.⁶ 1,3-Sigmatropic reactions are rare, occurring only under very favorable thermodynamic conditions.⁷ The apparent ease at which the group migrates in this case could be due to the migratory aptitude of the benzyl group and/or the instability of the enamine compared to the imine. Since **6** is also an enamine containing a *N*-benzyl substituent its nonrearrangement to **9** under the reaction conditions indicates there is probably additional instability associated with enamine **5**.

Instability of **5** compared to a normal enamine would not be unexpected since *N*-alkyl derivatives of the iso-electronic azepines are also known to be very unstable, a fact which can be attributed to the antiaromatic character of 8- π -electron systems.⁸

(6) Alternatively, as suggested by a referee, the reaction may not be concerted but could involve a diradical intermediate.

(7) R. B. Woodward and R. Hoffmann, "The Conservation of Orbital Symmetry," Verlag Chemie, Weinheim/Bergstr., Germany, 1970, p 114.

(8) (a) R. Breslow, J. Brown, and J. Gajewski, *J. Amer. Chem. Soc.*, **89**, 4383 (1967); (b) R. Breslow, *Angew. Chem., Int. Ed. Engl.*, **7**, 565 (1968).

Benzyl migration of **6** to give **9** probably does occur at higher temperatures and **9** is most likely the intermediate leading to 2,5-diphenyl-3,6-dibenzylpyrazine in the pyrolysis experiment. We are continuing our efforts toward an unambiguous synthesis of the 1,4-dihydropyrazine ring system.

Experimental Section⁹

1,6-Dibenzyl-2,5-diphenyl-1,6-dihydropyrazine (6).—To 4.00 g of phenacylbenzylamine hydrobromide was added 20 ml of a saturated Na_2CO_3 solution. The reaction mixture was stirred magnetically and refluxed for 1 hr. The red oil obtained was washed with hot water and then dissolved in ethanol. On standing overnight 0.55 g of yellow crystals precipitated, mp $150-155^\circ$. Recrystallization from ethanol gave the analytical sample: mp $153-157^\circ$; nmr (CDCl_3) τ 1.83-3.35 (m, 18 H, aromatics), 5.17 and 5.30 (two doublets, $J = 5.0$ Hz, 1 H), 6.15 (center of AB, $J = 15$ Hz, 2 H), and 6.83-7.62 (m, 2 H); ir (CHCl_3) 1602, 1495, 1445, 1347, and 694 cm^{-1} .

Anal. Calcd for $\text{C}_{30}\text{H}_{26}\text{N}_2$: C, 86.95; H, 6.28; N, 6.76. Found: C, 87.08; H, 6.40; N, 6.69.

Pyrolysis of 6.—To a 25.0×1.0 cm tube was added 372 mg of **6**. The tube was sealed under vacuum (10^{-5} Torr) and heated to 300° for 40 min. The nmr spectrum of the crude pyrolysate showed the presence of 2,5-diphenyl-6-benzylpyrazine (relative ratio 3:1:3) and toluene. The toluene was removed *in vacuo* and recrystallization of the residue gave 2,5-diphenylpyrazine: mp $194-196^\circ$ (lit.¹⁰ $195-196^\circ$); nmr (CDCl_3) τ 0.95 (s, 2 H) and 1.8-6.7 (m, 10 H). The mother liquors were concentrated and chromatographed on a thin-layer plate (1.5-mm silica gel eluted with 10% ether in benzene). The first band eluted was shown by nmr to be a mixture of 2,5-diphenylpyrazine and 2,5-diphenyl-6-benzylpyrazine. Repeated recrystallization from ethanol produced a very small amount of pure 2,5-diphenyl-6-benzylpyrazine: mp $98-99^\circ$; nmr (CDCl_3) τ 1.07 (s, 1 H), 1.8-3.3 (m, 10 H), and 5.75 (2 H, s). The second band off the tlc plate proved to be 2,5-diphenyl-3,6-dibenzylpyrazine: mp $145-147^\circ$; nmr (CDCl_3) τ 2.53 (s, 10 H), 2.83 (s, 10 H), and 5.72 (s, 4 H).

Anal. Calcd for $\text{C}_{30}\text{H}_{24}\text{N}_2$: C, 87.35; H, 5.82; N, 6.79. Found: C, 87.48; N, 5.82; N, 6.78.

1,6-Dibenzyl-3,5-diphenyl-1,6-dihydropyrazine (8).—To 2.0 g of diphenacylbenzylamine hydrobromide was added 1.0 g of benzylamine. The reaction mixture was heated in an oil bath at $120-130^\circ$ for 40 min. The now red-orange oil was triturated with ether and the benzylamine hydrobromide was filtered. Removal of the ether *in vacuo* gave a red-orange oil which crystallized from ethanol, mp $88-96^\circ$. Recrystallization from ethanol gave 0.78 g of yellow crystals: mp $94-98^\circ$; nmr (CDCl_3) τ 2.00-3.27 (m, 15 H), 3.42 (d, $J = 1.0$ Hz, 1 H), 5.17, and 5.30 (two doublets, $J = 5.0$ Hz, further coupled, $J = 1.0$ Hz, 1 H), 6.10 (q, $J = 15.0$ Hz, 2 H), and 6.87-7.50 (m, 2 H); ir (CHCl_3) 1592, 1493, 1452, 1342, and 692 cm^{-1} .

Anal. Calcd for $\text{C}_{30}\text{H}_{26}\text{N}_2$: C, 86.95; H, 6.28; N, 6.76. Found: C, 86.80; H, 6.41; N, 6.87.

1,6-Dibenzyl-3,5-diphenyl-1,6-dihydropyrazine (8).—To 20.4 g of diphenacylbenzylamine hydrobromide and 13.5 g of benzylamine was added 100 ml of benzene. The reaction was refluxed for 4 hr during which time the water was azeotropically removed with the aid of a Dean-Stark apparatus. The precipitate of benzylamine hydrobromide was removed by filtration and filtrate concentrated *in vacuo* to give an oily residue. This was dissolved in ethanol-ether and on standing over night 10.0 g of yellow crystals precipitated which proved to be **8**.

Pyrolysis of 8.—To a 25.0×1.0 cm glass tube was added 600 mg of **8**. The tube was sealed under vacuum (10^{-5} Torr) and heated for 40 min at 300° . The nmr spectrum of the crude product shows the presence of 2,6-diphenylpyrazine, 2,6-diphenyl-3-benzylpyrazine (relative ratio 5:6) and toluene. The products were purified by removal of the toluene *in vacuo* and chromatographing the residue on a thin-layer plate (1.5 mm silica gel eluted with 3:1 benzene ether). The first band eluted was recrystallized from ethanol and gave 2,6-diphenylpyrazine as

(9) Melting points are uncorrected. The microanalyses were performed by Gailbraith Laboratories, Knoxville, Tenn. Infrared spectra were determined with a Perkin-Elmer Model 137 Infracord. The nmr spectra were determined with a Varian A-60 spectrophotometer.

(10) Gerald Smolinsky, *J. Org. Chem.*, **27**, 3557 (1962).

colorless crystals: mp 80–81° (lit.⁴ 88–89); nmr (CDCl₃) τ 0.84 (s, 2 H) and 1.8–2.8 (m, 10 H).

Anal. Calcd for C₁₆H₁₂N₂: C, 82.76; H, 5.17; N, 12.06. Found: C, 82.93; H, 5.31; N, 11.84.

The second band was recrystallized from ethanol and gave 2,6-diphenyl-3-benzylpyrazine as colorless crystals: mp 98–99° (lit.⁴ 95°); nmr (CDCl₃) τ 1.05 (s, 1 H), 1.8–2.9 (m, 15 H), and 5.75 (s, 2 H).

Registry No.—6, 25827-90-1; 8, 25827-91-2; 2,5-diphenyl-6-benzylpyrazine, 25827-92-3; 2,5-diphenyl-3,6-dibenzylpyrazine, 25827-93-4; 2,6-diphenylpyrazine, 25827-94-5; 2,6-diphenyl-3-benzylpyrazine, 25827-95-6.

Acknowledgment.—This work was supported by the Research Foundation of the State University of New York.

Phytochemical Studies. IX. A New Flavone, Velutin¹

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Received April 14, 1970

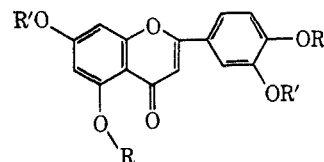
In connection with a projected phytochemical study of Washington vegetation, *Ceanothus velutinus*, a member of the Rhamnaceae or buckthorn family, was selected for initial examination. This shrub is distributed along the drier, east slopes of the Cascades and can be easily found in cleared timber areas. The leaf oil has been investigated in the past because of a pleasant odor, but only cinnamate esters were reported by earlier workers.²

A pentane extract of the leaves deposited a yellow powder, which was purified by crystallization from ethyl acetate. The resulting product or velutin analyzed for C₁₇H₁₄O₆ · 1/2 H₂O; however, a true molecular weight of 314 was given by mass spectroscopy. A positive ferric chloride test indicated a phenol, and, more specifically, magnesium–hydrochloric acid suggested a flavone. The presence of two hydroxyl groups was shown by the conversion of velutin into a diacetate, C₂₁H₁₈O₈.

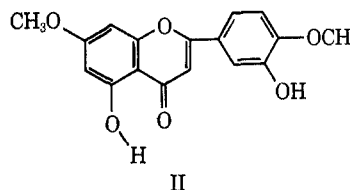
The infrared spectrum possessed a hydrogen-bonded conjugated carbonyl group and an extended aromatic ring system. In the ultraviolet, the main and secondary absorptions were similar to those reported for tetrasubstituted flavones.³ Generally, the shape of the bands implied the existence of hydroxyl or methoxyl substituents at the 3' and 4' positions in the flavone ring system. The nuclear magnetic resonance spectrum contained two singlet methoxy groups, an upfield pair of doublets with typical meta-coupling constants (centered on their chemical shifts), a singlet due to an olefinic hydrogen, a broad peak of three aromatic

hydrogens, and a hydroxyl shifted downfield due to hydrogen bonding. It will be noted that 13 of the 14 protons were definitely identified here; the missing hydroxyl proton probably exchanged with the water of solvation as detected in the microanalysis. These particular assignments were facilitated by use of an extensive compilation of flavone nmr data.⁴ A detailed solvent-shift study was not attempted because of the insolubility of velutin.^{5,6} The mass spectral fragmentation pattern was rationalized with the aid of known models,⁷ especially with flavones containing a 4'-hydroxyl group.⁸

The available chemical and spectral information was sufficient to postulate two alternative structures for the compound: 4',5'-dihydroxy-3',7'-dimethoxyflavone (Ia) or 3',5'-dihydroxy-4',7'-dimethoxyflavone (II). Ve-



- Ia, R = H; R' = CH₃
 b, R = Ac; R' = CH₃
 c, R = CH₃; R' = CH₃
 d, R = H; R' = H



lutin on exhaustive methylation formed luteolin tetramethyl ether (Ic), while demethylation produced luteolin (Id).⁹ These results verified both the substitution pattern and the ring system existing in the flavone. The crucial placement of the hydroxyl groups in both the A and B rings was made through ultraviolet studies. A shift of 48 m μ with sodium ethoxide in ethanol³ fixed one hydroxyl at 4' rather than 3', while a shift of 35 m μ with aluminum chloride in ethanol¹⁰ confirmed the placement of another hydroxyl group at 5. Compound Ia is known in the form of a dehydrogenation product from a naturally occurring flavanol,^{11,12} and the melting points and ultraviolet spectra of both it and the corresponding diacetate are in agreement with the present data.¹² Since comparison samples no longer exist,¹³ formula II cannot be completely excluded at this time. However, the weight of the evidence greatly favors Ia; so this structure is now assigned to velutin.

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(6) R. G. Wilson and D. H. Williams, *J. Chem. Soc. C*, 2477 (1968).

(7) A. Felner, P. Stainton, and M. Barber, *J. Heterocycl. Chem.*, **2**, 1262 (1965).

(8) H. Audier, *Bull. Chem. Soc. Fr.*, 2892 (1966).

(9) We thank Professor T. R. Seshadri, University of Delhi, for a sample of luteolin.

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(3) L. Jurd in "The Chemistry of Flavonoid Compounds," T. A. Geissman, Ed., Macmillan, New York, N. Y., 1962, p 107.