Tetrahedron. Vol. 32, pp. 2621 to 2623. Pergamon Press 1976. Printed in Great Britain

STUDIES IN THE CHEMISTRY OF ERYTHRINA ALKALOID DERIVATIVES—III

TWO ISOMERS OF 2,3,4,4a,5,6,7,7a,8,9,10,11-DODECAHYDRO-2,10-DIOXO-1*H*-BENZO[d]NAPHTHALENE

E. D. BERGMANN† and Y. MIGRON*
Department of Organic Chemistry, The Hebrew University, Jerusalem, Israel

(*Received in the UK* 26 *April* 1976; *Accepted for publication* 7 *June* 1976)

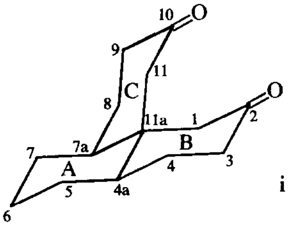
Abstract—Diketone 2,3,4,4a,5,6,7,7a,8,9,10,11-dodecahydro-2,10-dioxo-1*H*-benzo[d]-naphthalene prepared by annulation of N-(1-cyclohexenyl)pyrrolidine with vinyl methyl ketone, was found to consist of two stereoisomers. Theoretical dipole moments of these were calculated, and their structures were shown by moment dipole measurements to be *cis* A/B, *cis* A/C and *trans* A/B, *cis* A/C, respectively. The isomer *trans* A/B, *cis* A/C was converted into *trans* A/B, *cis* A/C dodecahydro-1*H*-benzo[d]naphthalene by the Wolff–Kishner reduction.

In the framework of our examination of structure-activity correlations in the erythrina alkaloids, dodecahydro-1*H*-benzo[d]naphthalene (**1**) was prepared, as an example of an all-carbon compound with the spirane system similar to the erythrina alkaloid. Hydrocarbon **1** was obtained by Wolff–Kishner reduction of the title compound.

On reinvestigation of the synthesis of the title compound from N-(1-cyclohexenyl)pyrrolidine and methyl vinyl ketone in ethanol we have found that the method reported by House *et al.*[1] leads to the formation of *two* isomeric diketones—one of m.p. 160–160.5° and one of m.p. 125.5–126.5° (**2a** and **2b** respectively). Both compounds which are easily separated by preparative GLC absorb at 1705 cm^{-1} and are transparent in the C=C region. This excludes the possibility of an α,β-unsaturated ketone structure. Their NMR spectra consist of complex multiplets at 1.5–2.8 ppm, free of any signals in the 5–6 ppm area. Both react with bromine sluggishly with evolution of HBr. The compound with the higher m.p. was converted to the corresponding hydrocarbon, dodecahydro-1*H*-benzo[d]naphthalene by Wolff–Kishner reduction.

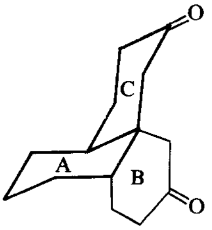
The diketones may exist in two of the following three geometric isomers:

(1) A/B *cis*, B/C *trans*



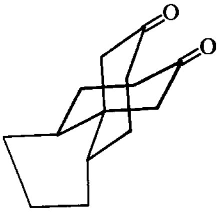
i

(2) A/B *cis*, A/C *cis*



ii

(3) A/B *trans*, A/C *trans*



iii

Dreiding models show that in the *trans–trans* and *cis–trans* forms, the angles formed by the two CO groups are identical but different from the corresponding angle in the *cis–cis* isomer. Consequently, the dipole moments of the *cis–trans* and *trans–trans* forms should be identical but different from that of the *cis–cis* structure.

In calculating the theoretical values for the dipole moments of the three compounds we have assumed that the cyclohexanone moieties, their bond angles and interatomic distances are conserved in the isomers i, ii and iii (an assumption which is justified in the case of those isomers, since the ring-angle distortions involved are relatively small). We adopted the coordinate values calculated by Eliel and Allinger[2] for cyclohexanone and set up for our molecule two coordinate systems analogous to those reported by them:[2] one, (x, y, z) with the origin at the first CO carbon: $C_2(000)$ and the other (x′, y′, z′) with the origin at the second CO carbon: $C'_{10}(000)$. The equations which transform the coordinates of the (x′, y′, z′) system into those in the (x, y, z) system are

$$x = t_{11}x' + t_{12}y' + t_{13}z' + t_{14} \tag{1.1}$$

$$y = t_{21}x' + t_{22}y' + t_{23}z' + t_{24} \tag{1.2}$$

$$z = t_{31}x' + t_{32}y' + t_{33}z' + t_{34}. \tag{1.3}$$

The coordinates of the carbonyl C atom C_{10} in (x, y, z) system are $C_{10}(t_{14}, t_{24}, t_{34})$. The coordinates of O_2 (the C-10 CO oxygen) which in the (x′, y′, z′) system are O'_2 $(-1.22, 0, 0)$, are transformed into $O_2(-1.22t_{11}+t_{14}, -1.22t_{21}+t_{24}, -1.22t_{31}+t_{34})$ in the (x, y, z) system, consequently, the components of the vector $\overline{C_{10}O_2}$ in the (x, y, z) are: $\overline{C_{10}O_2}(-1.22t_{11}, -1.22t_{21}, -1.22t_{31})$.

The equation for the molecular dipole moment is (2) $\mu = (\Sigma m_x)^2 + (\Sigma m_y)^2 + (\Sigma m_z)^2$ where Σm_i is the sum of the projections on the axis i of the vectors of all the group moments in the molecule. Σm_i is calculated as following

---

†Deceased on 5 April 1975.

$$\Sigma m_x = \frac{-1.22t_{11}\mu_{\mathrm{C=O}}}{[(1.22t_{11})^2 + [1.22t_{21})^2 + (1.22t_{31})^2]^{1/2}} - \mu_{\mathrm{C=O}}$$

$$= \frac{-[t_{11} + \sqrt{t_{11}^2 + t_{21}^2 + t_{31}^2}]\mu_{\mathrm{C=O}}}{\sqrt{t_{11}^2 + t_{21}^2 + t_{31}^2}} \tag{3.1}$$

$$\Sigma m_y = \frac{-t_{21}\mu_{\mathrm{C=O}}}{\sqrt{t_{11}^2 + t_{21}^2 + t_{31}^2}} \tag{3.2}$$

$$\Sigma m_z = \frac{-t_{31}\mu_{\mathrm{C=O}}}{\sqrt{t_{11}^2 + t_{21}^2 + t_{31}^2}} \tag{3.3}$$

where $\mu_{\mathrm{C=O}}$ is the dipole moment of the carbonyl group. By substitution of the values of Σm_i in the eqn (2) we obtain

$$\mu^2 = \frac{\mu^2_{\mathrm{C=O}}(t_{11}^2 + 2t_{11}\sqrt{t_{11}^2 + t_{21}^2 + t_{31}^2} + t_{11}^2 + t_{21}^2 + t_{31}^2 + t_{21}^2 + t_{31}^2)}{t_{11}^2 + t_{21}^2 + t_{31}^2}$$

$$= \frac{\mu^2_{\mathrm{C=O}} \cdot [2t_{11}\sqrt{t_{11}^2 + t_{21}^2 + t_{31}^2} + 2(t_{11}^2 + t_{21}^2 + t_{31}^2)]}{t_{11}^2 + t_{21}^2 + t_{31}^2}. \tag{4}$$

The cartesian systems (x, y, z) and (x′, y′, z′) imply orthogonal transformation matrices so that $t_{11}^2 + t_{12}^2 + t_{13}^2 = 1$. Substitution of this value in the eqn (4) results in (5) $\mu^2 = 2\mu^2_{\mathrm{C=O}}(t_{11} + 1)$. To obtain t_{11} we have to solve (1.1). By substituting the coordinates values x′, y′, z′ and x of the atoms C_1, C_{11a}, C_{4a} and C_{11} we get four simultaneous linear equations with four unknowns t_{11}, t_{12}, t_{13}, t_{14}. The coordinate values of the above-mentioned atoms in the *cis–cis* form isomer are:

C'_1	$(0.585 \times 1.53 + 1.868,\ 0.804 \times 1.53 + 1.265,\ -0.103 \times 1.53 + 1.09)$
C'_{11a}	$(1.868,\ 1.265,\ 1.090)$
C'_{4a}	$(-0.436 \times 1.53 + 1.868,\ +0.063 \times 1.53 + 1.265,\ 0.898 \times 1.53 + 1.090)$
C'_{11}	$(0.795,\ 1.272,\ 0)$

C_1	$(0.795,\ -1.272,\ 0)$
C_{11a}	$(1.868,\ -1.265,\ 1.090)$
C_{4a}	$(2.726,\ 0,\ 1.028)$
C_{11}	$(0.436 \times 1.53 + 1.868,\ -0.063 \times 1.53 - 1.263,\ 0.898 \times 1.53 + 1.090).$

The solution of these equations gives $t_{11} = 0.0784$, and hence $\mu_{\text{theoretical}} = 2\mu^2_{\mathrm{C=O}}(t_{11} + 1) = 4.523\mathrm{D}$ ($\mu_{\mathrm{C=O}}$ for cyclohexanone $= 3.08\mathrm{D}$[3]). The coordinate values in the *cis–trans* and *trans–trans* isomers are:

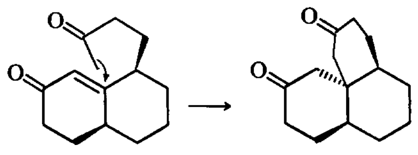
C'_1	$(-0.436 \times 1.53 + 1.868,\ +0.063 \times 1.53 + 1.265,\ -0.898 \times 1.53 - 1.090)$
C'_{11a}	$(1.868,\ 1.265,\ -1.090)$
C'_{4a}	$(0.585 \times 1.53 + 1.868,\ 0.804 \times 1.53 + 1.265,\ +0.103 \times 1.53 - 1.090)$
C'_{11}	$(0.795,\ 1.272,\ 0)$

C_1	$(0.795, -1.272, 0)$
C_{11a}	$(1.868,\ -1.265,\ 1.090)$
C_{4a}	$(2.726,\ 0,\ 1.028)$
C_{11}	$(-0.436 \times 1.53 + 1.868,\ -0.063 \times 1.53 - 1.265,\ 0.898 \times 1.53 + 1.090).$

It follows that $t_{11} = 0.946$ and $\mu_{\text{theoretical}} = 6.077\mathrm{D}$.

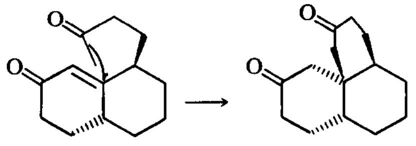
Dipole moments measurements were carried out by the Halverstadt-Kumler[4] method. The value found for the higher melting isomer is $5.92 \pm 0.01\mathrm{D}$; which is in agreement with the theoretical moment for the *trans–trans* or *cis–trans* isomer. The experimental dipole moment for the lower melting isomer is $\mu = 4.47 \pm 0.03\mathrm{D}$, which matches the calculated value for the *cis–cis* isomer. We attribute the small difference between the calculated and measured values to minute distortions in the molecule due to dipole and/or steric repulsions.

The *cis–trans* and *trans–trans* isomers can neither be distinguished from each other by dipole moment measurements, nor by NMR spectroscopy, even in the presence of shift reagents. The ^{13}C NMR spectrum of the higher melting substance shows fourteen peaks corresponding to fourteen carbon atoms, two of which at a lower field (209.59 and 208.75 ppm) corresponding to carbonyl carbons. This indicates that only one of the two possible isomers is present. If we consider that owing to steric factors, ring A in the *trans–trans* compound must be in the boat form, we can conclude that it is less stable than the *cis–trans* isomer. Furthermore, the fact that these compounds are formed in a Michael type reaction,[1] which is known to be reversible, and to proceed under thermodynamic control,[5] supports preferential formation of the *cis–trans* isomer. Apparently the latter species is obtained from *cis* 8-(1-butane-3-one)$\Delta^{9,10}$ octalone (**3**), and the *cis–cis* isomer from *trans* 8-(1-butane-3-one)$\Delta^{9,10}$ octalone (**4**). Both via axial attack on the respective C_{10} trigonal carbon (see Schemes 1 and 2, respectively).



3 *cis,trans*

Scheme 1.



4 *cis,cis*

Scheme 2.

EXPERIMENTAL

M.ps were obtained using the Thomas–Hoover capillary m.p. apparatus. IR spectra were recorded with a Perkin–Elmer 457

Grating Infrared Spectrophotometer and NMR spectra with Varian T-60 and Varian HA 100D NMR spectrometers. Mass spectra were obtained with a Massenspectrometer Mat 311, Varian Mat Brenen, and GLC separation were conducted with an Aerograph A 90-P3 instrument.

Two isomers of 2,3,4,4a,5,6,7,7a,8,9,10,11 - *dodecahydro* - 2 - 10 - *dioxo* - 1H - *benzo*[d]*naphthalen* (**2b** and **2b**)

According to House *et al.*[1] N-(1-cyclohexenyl)pyrrolidine (44.6 g, 0.295 mole) and methyl vinyl ketone (54 g, 0.9 mole) in EtOH (200 ml) were reacted to give an oil (63 g) which partially solidified on standing. Crystallization from acetone–petroleum ether afforded *cis–trans* isomer **2a** (10 g, 15.4% yield) as needles, m.p. 160–160.5° (lit.[1] 160–162°) (from isopropenol). Mass spectrum (70 eV) *m/e* 220 (M^+); NMR ($CDCl_3$): δ 1.5–2.8 (multiplet), IR (Nujol): 1705 cm^{-1} (C=O). (Found: C, 76.43; H, 9.07. Calc. for $C_{14}H_{20}O_2$: C, 76.36; H, 9.09%). Retention time in GLC (15% SE 30 on chromosorb P at 205°, 180 cm × 1/4 in., Helium velocity: 60 cm/min): 7.2 min. Dipole moment: calculated as 6.077D, found: 5.92 ± 0.01D. The *cis–cis* isomer **2b** was obtained as a mixture with **2a** on fractionation of the mother liquors. The fraction 140–160° (0.5 mm) yielded on crystallization from isopropanol a colourless solid (3.1 g) which was separated by preparative GLC (15% SE30 on chromosorb P at 205°, 180 cm × 1/4 in., Helium velocity 60 cm/min) to afford isomer **2a** (41.8%) in a retention time of 7.2 min, and isomer **2b** (58.2%) in a retention time of 5.5 min. **2b** is a colourless solid, m.p. 125.5–126.5°. Mass spectrum (70 eV) *m/e* 220 (M^+). NMR ($CDCl_3$): δ 1.5–2.8; IR (Nujol): 1705 cm^{-1} (C=O). (Found: C, 76.45; H, 9.21. Calc. for $C_{14}H_{20}O_2$: C, 76.36; H, 9.09%). Dipole moment: calculated as 4.523D, found: 4.47 ± 0.3D.

Dipole moment measurements. The dipole moments were calculated according to Halverstadt and Kumler[4] from measurements carried out at $30.0 \pm 0.1°$ in C_6H_6. Dialectric constants were measured with a Heterodyne beat instrument (50 kc/s). Specific volumes were determined with an Oswald Sprengel type pycnometer and the refractive indice with a sodium lamp Bellington and Stanley Pulfrich refractometer.

Measurement of the solution of **2a** gave $\alpha' = 47.997$, $\beta' = 0.878$, $R_2 = 63.05$; consequently, $P_\infty = 766.678$ and $\mu = 5.92 \pm 0.01$D. Similarly for the solution of **2b**: $\alpha' = 27.391$, $\beta' = 0.014$, $R_2 = 81.36$ so that $P_\infty = 482.879$ and $\mu = 4.47 \pm 0.030$D.

We are indebted to Dr. Wiler-Feilchenfeld for those measurements and calculations.

cis *A/B*, trans *B/C Dodecahydro*-1H-*benzo*[*d*]*naphthalen* (**1**) prepared from the *cis–trans* isomer (**2a**) by the Wolff–Kishner reduction. To a solution of **2a** (4.7 g, 0.0214 mole) and hydrazine hydrate (10.7 g, 0.217 mole) in diethylene glycol (100 ml) refluxed for 1 hr, a soln of KOH (4 g) in diethylene glycol was added. After reflux for 45 min the resulting water and excess of hydrazine hydrate were distilled away until liquid temp. reached 180°. Heating was then continued under reflux, at 190–195° for 4 hr. The mixture was cooled, poured into water and extracted with cyclohexane. The organic layer was washed successively with water, dil HCl aq and water, dried ($MgSO_4$) and evaporated. The residue, a colourless liquid (4 g, quantitiative yield) gave only one peak on GLC. Retention time in GLC (15% SE 30 on chromosorb P at 205°, 180 cm × 1/4 in., Helium velocity: 60 cm/min): 1.4 min. b.p. 136–8°/20 mm. IR (neat): 2970, 1450 cm^{-1} (typical of cyclic hydrocarbons). (Found: C, 87.33; H, 12.55. Calc. for $C_{14}H_{24}$: C, 87.50; H, 12.50.

^{13}C NMR *spectrum of* **2a** was recorded on Varian CFT-20 spectrometer at 20 MHz in $CDCl_3$ solution. Signals are shown at: 209.59 (C=O), 208.75 (C=O), 51.27, 44.37, 43.42, 41.11, 40.57, 39.61, 36.08, 27.41, 27.03, 26.05, 25.79, 25.22 ppm.

REFERENCES

[1] H. O. House, B. M. Trost, R. W. Magin, R. G. Carlson, R. W. Frank and G. H. Rassmuson, *J. Org. Chem.* **30**, 2513 (1965).
[2] L. L. Eliel, N. L. Allinger, S. J. Angyal and G. A. Morrison, *Conformational Analysis*, p. 454. Wiley, New York (1965).
[3] H. H. Günthard and T. Gaumann, *Helv. Chem. Acta* **34**, 39 (1951).
[4] I. F. Halverstadt and W. D. Kumler, *J. Am. Chem. Soc.* **64**, 2988 (1942).
[5] N. L. Allinger and C. K. Riew, *Tetrahedron Letters* 1269 (1966).