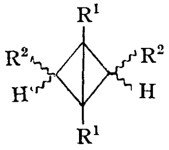
The Three Geometrical Isomers of a 2,4-Disubstituted Bicyclobutane

By J. H. LEFTIN, E. GIL-AV,* and A. PINES

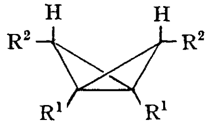
(*Department of Chemistry, The Weizmann Institute of Science, Rehovoth, Israel*)

A CONSEQUENCE of the nonplanar structure of bicyclobutane[1] is the possible existence of three geometrical isomers for compounds such as (I) and (II), which have substituents ($R^2 \neq H$) in positions 2 and 4. So far, however, synthesis of such derivatives has led to only one isomer (*exo,exo*)[2–5] with the notable exception of (I), for which D'yakonov and his co-workers recently reported the formation of a second form (*exo,endo*).[3] These authors commented on their failure to detect any *endo,endo*-compound, and suggested that this isomer might be too unstable to exist.

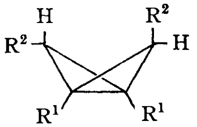
We now report the isolation of an isomer (IIc) having the hitherto unknown *endo,endo*-configuration. An additional *exo,endo*-compound has been characterized. Three geometric forms of a 2,4-symmetrically disubstituted bicyclobutane (IIa—IIc) have thus been found for the first time.



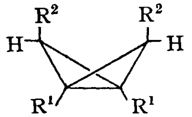
(I)R^1=Ph, R^2=CO_2Et
(II)R^1=Pr^n,R^2=CO_2Me



(Ia, IIa,)
(*exo, exo*)



(Ib, IIb)
(*exo,endo*)



(Ic, IIc)
(*endo, endo*)

Compound (II) was prepared by the reaction of methyl diazoacetate on methyl 1,2-di-n-propylcyclopropene-3-carboxylate at 120—130°, using a copper powder catalyst. The fraction boiling at 90—100°/0·5 mm. was chromatographed at 175° on a 5·2 m. × 0·25 in. copper column, packed with Chromosorb W (30—60 mesh) coated with 30% Edwards High Vacuum Silicone Grease. Three peaks appeared in the chromatogram, having retention times of 68·2, 77·7, and 82·9 min. (from air peak) and with areas corresponding to 77·6, 17·1, and 5·4%, respectively. Samples corresponding to each of these peaks were isolated by preparative gas chromotography in 95—98% purity.

A compound of structure (II) has previously been synthesized by Wolf[5]† and was assigned the *exo,exo*-configuration. The physical and spectral properties of our compound (IIa) are identical with those of the product of the above authors.

The new products, (IIb) and (IIc), have been recognized as bicyclobutane derivatives isomeric with (IIa). The mass spectra of the three compounds (IIa—c) exhibited the same value, *i.e.* *m/e* 254, for the molecular ion, and the elemental analyses agreed satisfactorily with the formula $C_{14}H_{22}O_4$. The three i.r. spectra were practically identical. The presence of an ester carbonyl absorption at 1750 cm.$^{-1}$ and signals in the n.m.r. spectrum due to six methoxy-protons in the narrow range of 3·58—3·68 p.p.m. (see Table) proved the presence of two methoxycarbonyl groups in the molecule. As no absorption due to unsaturation was observed in the i.r. and u.v. spectra (and also no signals due to vinylic protons in the n.m.r. spectra), the diester of the above formula must have a saturated bicyclic structure.

The n.m.r. spectra of (IIb) and (IIc) are analogous to that of (IIa) and are fully compatible with all the features of a dimethyl ester of 1,3-di-n-propylbicyclobutane-2,4-dicarboxylic acid. The detailed interpretation of the n.m.r. spectra in terms of the n-propyl groups attached to a tertiary carbon, the ring protons, and the methoxycarbonyl groups is given in the Table.

Compound (IIb) has been assigned the *exo,endo*-configuration, since the n.m.r. spectrum shows two nonequivalent ring protons (singlets at 2·16 and 2·66 p.p.m.) and two nonequivalent methoxy-groups (singlets at 3·58 and 3·64 p.p.m. due to three protons each).

Compound (IIc) is clearly the *endo,endo*-isomer. Its n.m.r. spectrum shows two equivalent ring protons (singlet at 2·67 p.p.m.), whereas the methoxy-groups gives rise to two singlets, corresponding to three protons each, at 3·60 and

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† D'yakonov and his co-workers have prepared a homologue with R^1 = Pr and R^2 = CO_2Et (ref. 4).

N.m.r. spectra[a] *of bicyclobutane derivatives*

Compound	Gas chromatog. peak no.	Configuration	Assignment of n.m.r. absorption (p.p.m., number of protons, multiplicity)				
			OCH_3	Ring protons	$-C-CH_2^{\alpha}-CH_2^{\beta}-CH_3^{\gamma}$		
					α	β	γ
(IIa)	1	*exo,exo*[b]	3·68,6H singlet	1·28,2H singlet	2·07,4H triplet	1·46,4H multiplet	0·91,6H triplet
(IIb)	2	*exo,endo*	3·58,3H singlet; 3·64,3H singlet	2·16,[c]1H singlet; 2·66,1H singlet	2·17,4H triplet	1·52,4H multiplet	0·97,6H triplet
(IIc)	3	*endo,endo*	3·60[d],3H singlet; 3·65,3H singlet	2·67,2H singlet	2·41,4H triplet	2·51,4H multiplet	0·94,6H triplet

[a] Measured in $CDCl_3$ with a A60 Varian n.m.r. spectrometer, using Me_4Si as internal reference.

[b] The n.m.r. data are identical with those reported by Wolf (ref. 5).

[c] The singlet at 2·16 p.p.m. due to one of the ring protons, overlaps with the triplet at 2·17 p.p.m., but is nevertheless clearly recognizable.

[d] Measured at room temperature; see text for values at other temperatures.

3·65 p.p.m. (in $CDCl_3$). As can be seen on models, the *endo,endo*-isomer differs from the two other geometrical forms of (II) by the considerable spatial compression of the methoxycarbonyl groups. Consequently, nonequivalence of the methoxy-groups, as observed in the n.m.r. spectrum, can readily result from hindrance to free rotation. As the temperature is increased from −17·5° to +195°, the chemical shift between the protons of the two methoxy-groups of (IIc) decreases from 3·25 to 1·40 c./sec. (in hexachlorobutadiene). The non-occurrence of coalescence of the signals, even at as high a temperature as 195°, is in agreement with the overcrowded structure of the *endo,endo*-compound. The effect of the temperature is being further investigated.

The present data provide additional evidence for the correctness of the assignment of the *exo,exo*-structure to the isomer of (II), prepared previously.[5] In fact, since (IIc) has been found to have nonequivalent methoxy-groups, it follows that the equivalence of the protons of the two methoxy-groups of (IIa) (3·68 p.p.m., 6H, singlet: Table) is unequivocal proof for the *exo,exo*-configuration.

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