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COUPLED RING REVERSAL IN TRANS-1,5-diMe-2,4-DIOXASPIRO[5.5]-UNDECANE.

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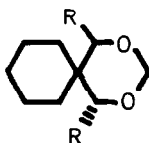
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There are two degenerate chair forms of cyclohexane, and four (2^2) degene-
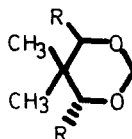rate (equienergetic) all-chair forms of spiro [5.5]-undecane (I).

| I | IIa R = H | IIIa R = H |
| | IIb R = Me | IIIb R = Me |

Table I : Free activation energies $\Delta G^{\neq}$ (kcal/mole) for 1,3-dioxane derivatives
studied CS_2 solvent.   Error on $\Delta G^{\neq}$ 0.1 to 0.15 kcal/mole.

| IIa | $\Delta G^{\neq}_{208}$ | 10.1 | IIIa | $\Delta G^{\neq}_{216}$ | 10.6 |
| IIb | $\Delta G^{\neq}_{231}$ | 11.4 | IIIb | $\Delta G^{\neq}_{204}$ | 10.0 |

We call the two chair forms in cyclohexane α and β, and the ring topomerization
(2) α ⇌ β transitions. By an obvious extension, the four all-chair forms of I
may be labelled as αα, αβ, βα and ββ. The transition αβ ⇌ ββ and αα ⇌ ββ
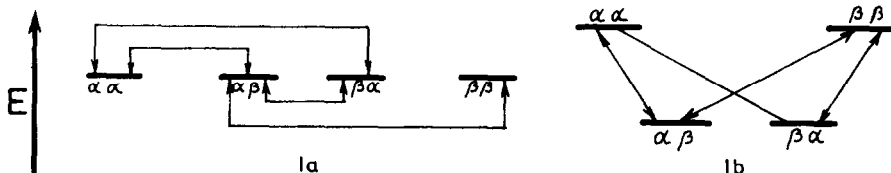require one and two ring reversals respectively (fig. 1a).

Fig. 1.   One ring reversals in spiro[5.5]-undecane derivatives.

The influence of a spiro linkage on the thermodynamic parameters for ring inver-
sion in comparison with the individual rings has been studied by Greenberg and

Laszlo (3). They were the first to suggest the possibility of a concerted in-
version. In cyclohexane the degeneracy of α and β may be lifted by the intro-
duction of a substituent, resulting in the well known conformers with equatorial
and axial substituents. In spiro[5.5]-undecane two identical substituents may
be introduced,so that the degeneracy is partially lifted, e.g.,we may have two
different pairs of degenerate all-chair forms say αα,ββ and αβ,βα so that inter-
conversion between each of the two equienergetic conformers formally requires
two consecutive reversals, one for each ring (fig. 1b). This raises the fol-
lowing intrigueing question : is it not possible to provide for a pathway for
interconversion of the low energy pair (αβ,βα in fig. 1b) so that both rings
are <u>simultaneously</u> involved in the transition αβ $\rightleftarrows$ βα ?
Consider the title compound, (IIb),where the 1,3-dioxanic moiety serves pri-
marily conveniently to determine the free activation energy by variable tempe-
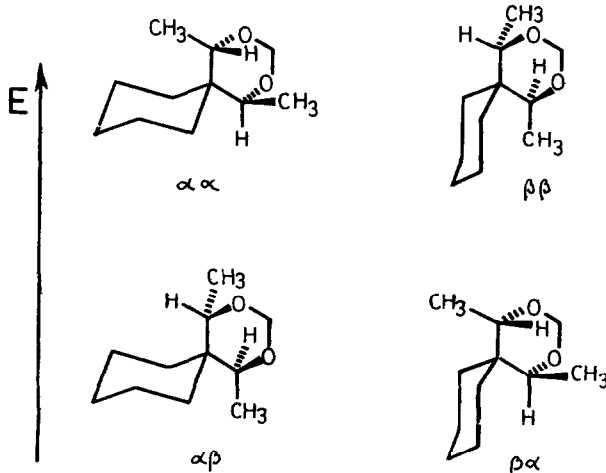rature NMR spectroscopy. The four chair conformers of IIb are shown in fig. 2.

Fig. 2. Chair conformers of title compound IIb.

Clearly αα and ββ should be very strained. One of the methyl groups attached
to the 1,3-dioxanic moiety sticks above the plane of the cyclohexane part in
a way reminiscent of the unfavourable aspects of an axial <u>t</u>.Bu group. There-
fore one could imagine that during the transformation of αβ to ββ, the in-
creasing strain causes the other ring to flip concertedly,with the net result
of an αβ $\rightleftarrows$ βα transition.
We found by ^{1}H-NMR spectroscopy (CS$_2$ solvent, 100 MHz) by a variable tempera-

ture study of the 1,3-dioxanic moiety,free activation energies for IIa and IIb

of $\Delta G_{208}^{\neq}$ 10.1 and $\Delta G_{231}^{\neq}$ 11.4 kcal/mole respectively, the latter being the

highest ever reported for a non-annellated 1,3-dioxane derivative. It might

be argued that the increase of the free activation energy observed on going

from IIa to IIb is due to a destabilisation of the transition state originating

in the eclipsing strain of the methyl groups on C1/C5 and the methylene groups

on C6 on the other hand. In this case a similar increase of $\Delta G^{\neq}$, on going

from 5,5-diMe- to trans-4,5,5,6-tetraMe-1,3-dioxane (IIIa → IIIb) is expected.

Experimentally however IIIb has a lower barrier to ring inversion than IIIa[x].

We therefore feel justified in suggesting that the difference in free activa-

tion energy between IIa and IIb is sufficiently large to be ascribed to a

coupling of the ring reversals in trans-1,5-diMe-2,4-dioxaspiro[5.5]-undecane

(IIb). It remains a difficult point to determine how large exactly the ener-

getic contribution is of the "coupling" to the $\Delta G^{\neq}$ value in IIb. Research

towards that goal is currently under way.

In summary, we may say that the present study illustrates the operation

in the transition state of a "gear-effect" (5), i.e. a strong conformational

correlation between non-bonded groups.

The title compound was prepared by alkylation of pentanedione-2,4 with

1,5-dibromopentane, reduction with sodium borohydride and ring closure of the

1,3-diol with formaldehyde. The cis and trans isomers were separated by GC,

the trans isomer (IIb) having the greater retention time.

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x

These data do not imply that eclipsing strain should be unimportant. Axial
methyl groups in C4/C6 position of a 1,3-dioxane ring however cause a lowering
of the barrier to ring inversion. Thus for 4,4-diMe-1,3-dioxane the free
activation energy to ring topomerization is reported (6) to be $\Delta G_{172}^{\neq}$ = 8.6
kcal/mole. Also we have observed for trans-4,6-diMe-1,3-dioxane $\Delta G_{163}^{\neq}$ = 8.2
kcal/mole (1,3-dioxane $\Delta G_{191}^{\neq}$ = 9.7 kcal/mole (4)). This low barrier is un-
doubtedly related to the large conformational free energy of a 4-Me group
in 1,3-dioxane (6,7). It therefore appears that the relatively high barrier
in IIIb is due to the largely cancelling effects of (i) destabilisation of
the ground state by the 4-axial methyl group (ii) destabilisation of the
transition state due to the eclipsing strain.

NMR parameters (see for IIa also (4)) :

(i) $T > T_c$; δ(H-3) 4.68, δ(H-1/5) 3.82, δ(Me-1/5) 1.14; (ii) $T < T_c$; δ(H-3e) 4.42, δ(H-3a) 4.73, δ(H-1e) 4.13, δ(H-5a) 3.59, δ(Me-1a) 1.23, δ(Me-5e) 0.99. T_c = 231 K.

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