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STRUCTURE ELUCIDATION WITH LANTHANIDE INDUCED SHIFTS. 9. BICYCLO[3.3.1]NONAN-9-ONE

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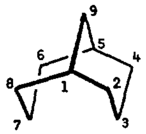
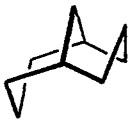
Lanthanide shift reagents have been used for the conformational analysis of bicyclo[3.3.1]-nonan-9-one. Comparison of predicted shifts and experimental values obtained with Eu(fod)$_3$ indicate that the boat-chair conformation constitutes 22% of the mixture of conformers.

Bicyclo[3.3.1]nonane (1) and its derivatives have been of considerable interest to organic chemists for many years,[1-3] The nonbonded interactions which are anticipated for the dichair conformation (1a) have generated a high degree of interest in these compounds as possible examples of cyclohexanes with nonchair conformations (1b and 1c). Moreover, the potential for interaction between substituents on the two cyclohexane rings has permitted bicyclo[3.3.1]nonane derivatives to play valuable roles as substrates for mechanistic studies[4-6] and as synthetic intermediates.[7-10] The parent compound 1 has been clearly shown[11] to exist in the dichair conformation, although the interaction between substituents at the 3 and 7 positions can shift the conformational equilibrium such that the chair-boat (2b) predominates.[12] These conclusions from experimental observations are fully supported by a variety of empirical force field (EFF) calculations.[13-16] In this communication we report an example of a simple bicyclo[3.3.1]nonane derivative which exists to a substantial extent in the boat-chair conformation -- <u>not</u> because of destabilizing the dichair conformation, but as a consequence of <u>stabilization</u> of the boat-chair.

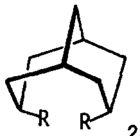


1a

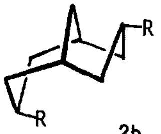


1b

1c

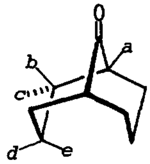


2a

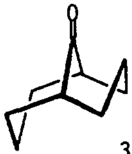


2b

The presence of the carbonyl group in bicyclo[3.3.1]nonan-9-one (3) is expected to decrease the unfavorable nonbonded interactions of the boat conformation, and consequently a shift in the conformational equilibrium seemed likely. We therefore undertook a study of lanthanide induced shifts (LIS) of 3 using Eu(fod)$_3$ in CCl$_4$.[17] The bound shifts of the 1:1 complex were obtained by the incremental dilution method,[17] and these were compared with predicted values which were calculated using the pseudocontact equation.[18] The calculations were carried out using the geometry obtained from EFF calculations[19] for the ketone moiety with an oxygen-europium bond length of 2.50 Å and a C-O-Eu angle of 180° as expected for a ketone with C_{2v} symmetry.[20] The results are summarized in the Table. The agreement factor of 0.049 obtained from the calculation for the dichair conformation was well above the value of 0.03 which we have found to be a reasonable upper limit for an acceptable structural hypothesis.[21]



3a



3b

Table. Experimental and Calculated LIS for Bicyclo[3.3.1]nonan-9-one with Eu(fod)$_3$.[a]

Hydrogen Type[b]	Calculated (100% Dichair Conformation)[c]	Experimental	Calculated (22% Chair-Boat Conformation)[d]
b	8.79	8.55	8.57
c	5.60	5.56	5.68
d	4.56	5.20	5.18
e	5.24	5.57	5.25

[a] Calculated with $\Delta_1 = k(3\cos^2\theta-1)/r^3$, where k = 976.6 and geometry was obtained from EFF calculations. [b] See structure 3a; the α-hydrogens (type a, Δ_1 = 16.65) are excluded because of contact shift. [c] Agreement factor = 0.049 with exp. shifts scaled by a factor of 0.071 (see ref. 20). [d] Agreement factor = 0.022 with exp. shifts scaled by a factor of 0.965.

Therefore we repeated the calculations for a series of conformational mixtures of the dichair (3a) and chair-boat (3b) conformations.[22] The agreement factor exhibits a distinct minimum (see Figure) for the distribution of 78% dichair (3a) and 22% of the chair-boat (3b). This clearly requires revision of the accepted conformation of bicyclo[3.3.1]nonan-9-one as the dichair,[23] but is consistent with Sorensen's finding from ^{13}C nmr studies that the analogous tertiary carbocation (the 9-bicyclo[3.3.1]nonyl cation) exists substantially in the chair-boat conformation.[24] Our results further demonstrate the power of lanthanide shift reagents for conformational analysis,[25-27] and indicate that considerable caution should be exercised when attempting to evaluate experimental data for bicyclo[3.3.1]nonane derivatives in terms of a single conformation.[28]

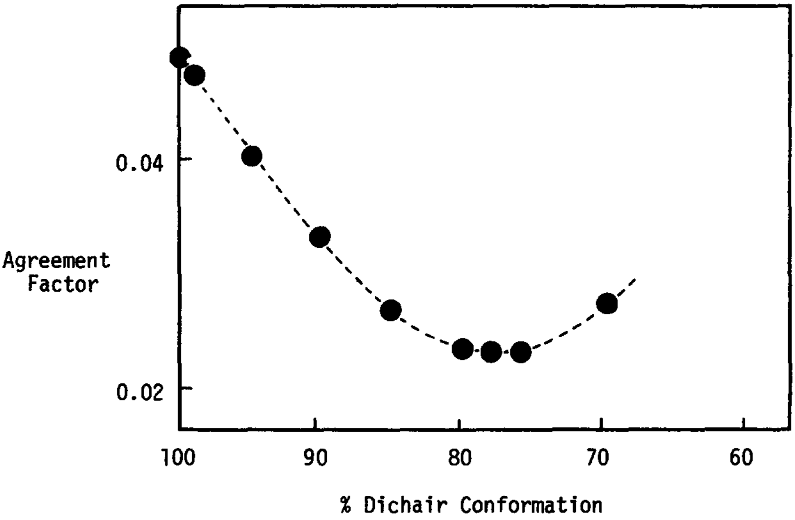


Figure. Plot of Agreement Factor (see ref. 18) between experimental and calculated LIS for various distributions of conformations **3a** and **3b**.

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22. On the basis of EFF calculations[18] the dichair conformation (**3a**) has a strain energy of 10.3 kcal/mol while that of the chair-boat (**3b**) is 11.4 kcal/mol. The substantially higher 16.0 kcal/mol for the diboat (considered to be outside the range of errors for calculations with the Allinger MM1 force field) permitted that conformation to be excluded from our analysis.

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