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ATTRACTIVE INTERACTION BETWEEN ALIPHATIC AND AROMATIC SYSTEMS

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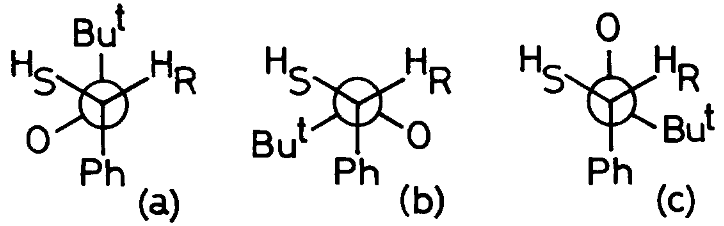
In connection with general interests in the conformational problems of aliphatic molecules, we studied the effect of benzene and a lanthanide shift-reagent (LSR) on the proton n.m.r. spectrum of benzyl t-butyl sulphoxide (1).

Non-deuteriated 1 shows, in CCl_4, a benzylic AB-quartet centred at 3.66 and 3.46 ppm (J = 12Hz) from internal TMS. The mono-deuteriated species, (αR,SS/αS,SR)-1-d and (αR,SR/αS,SS)-1-d[1] give rise to triplets (J_{HD}= 1.8Hz) at 3.45 and 3.65 ppm, respectively, allowing the assignment of each signal, the higher and the lower one corresponding to the pro-R (H_R) and pro-S (H_S) hydrogen in (R)-sulphoxide, respectively (Fig. 1).

Fig. 1

Various Conformers of (R)-1



It was very striking that the peaks attributed to H_R showed more pronounced shift by addition of a LSR whereas H_S showed more profound aromatic solvent-induced shift (ASIS). One might expect the entirely opposite trend if the conformer having t-Bu anti to Ph (a) is assumed to be most populated. The results, together with those for p-substituted derivatives, are listed in Table 1.

We further carried out a computer simulation to the LIS (LSR-induced shift) in the spectrum of 1. According to the procedure reported elsewhere,[2] the Ln-O distance (R), the dihedral angle (ψ) defined by O-S-C-C(Ph) and A (a Gaussian weight factor for the Ln-distribution) were allowed to vary to obtain the best fit with the experimental values. The best agreement (Table 2) was obtained at R = 3.6Å, ψ= 100° (Fig. 2) and A = 0.6. This requires that the "bulkiest" group (t-Bu) in 1 orients itself gauche to Ph, the dihedral angle defined by C(Bu)-S-C-C(Ph) being ca. 20°. This is consistent with the ORD[3] and dipole moment data.[4]

A strong support for this conformation comes from the diastereotopos differentiating reactions of 1.[5] It has unequivocally been shown that one of the

TABLE 1

	MeO		Me		H		Br		NO_2	
	H_R	H_S	H_R	H_S	H_R	H_S	H_R	H_S	H_R	H_S
CCl_4^a	3.40	3.60	3.41	3.61	3.46	3.66	3.40	3.59	3.55	3.71[b]
ASIS[c]	0.06	0.26	0.08	0.28	0.15	0.35	0.30	0.49	0.48	0.64
LIS[d]	-2.16	-1.34	-2.15	-1.44	-2.14	-1.45	-2.03	-1.27	-2.22	-1.34

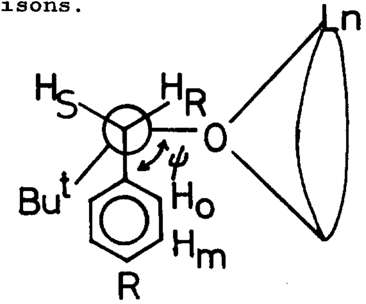
[a] 0.1 mmole/0.6ml solvent. [b] ppm downfield from internal TMS. [c] $\delta CCl_4 - \delta$benzene. [d] $\delta CCl_4 - \delta$LSR: 0.2 equiv. of $Eu(fod)_3$ was added. Assignment for these protons (except for 1, R = H[1]) was made by spectral comparisons.

TABLE 2

	H_R	H_S	H_o	H_m	t-Bu
[a] obs.	1.00	0.61	0.38	0.11	0.49
calc.	1.00	0.56	0.38	0.11	0.50

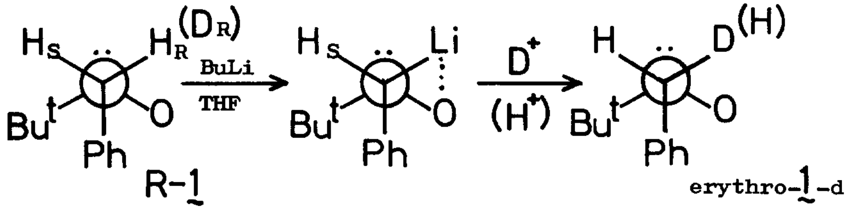
[a] Relative slopes of LIS vs (LSR)/(substrate).

Fig. 2



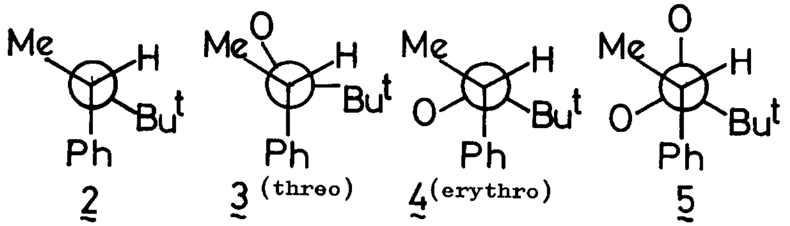
diastereotopic hydrogens (H_R or D_R) in R-1 is exclusively abstracted and the intermediate carbanion gives erythro-1-d, on quenching it with a deuterium cation (Fig. 3).[6] The result (stereospecific abstraction of H_R and retention of the configuration at the final step) can only be rationalysed on the basis of the suggested conformation.

Fig. 3



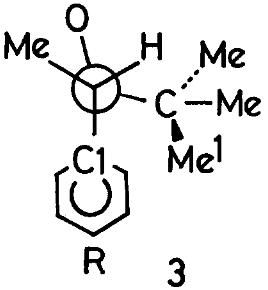
Above facts, along with earlier observations regarding the conformations of 1-phenylethyl sulphide (2)[7], sulphoxides (3 and 4)[3,4,8] and sulphone (5)[9] seriously challenge the current discussions of conformational analyses; the generally accepted basis of the conformational analyses (bulk repulsive concept) does not hold, in these cases at least. In all cases examined so far[10] the t-butyl group was found to orient itself gauche with respect to the phenyl group (Fig. 4).

Fig. 4



An interpretation is possible for the conformations of 1-phenylethyl compounds (2 - 5) in terms of the "effective size" of the relevant groups (Me>Ph).[3,7,11] The t-Bu/Me interaction, however, is lacking in 1. We must therefore seek a possibility that an alkyl group (a Me on the t-Bu carbon atom in this case) has an affinity with an aromatic group, in this molecular environment at least.[12] This suggestion finds a support in the X-ray result. Thus the carbon atom of a methyl group in t-Bu (Me1, Fig. 5) has been shown, in 3 and 4, to be very proximate to one of the carbon atoms (C1) of the phenyl ring.[3] The interatomic distance C(Me1)-C1 is ca. 3.3A in both compounds (R = Br).[13] Note that this is shorter than the sum of the van der Waals radii of the relevant atoms or groups.

Fig. 5



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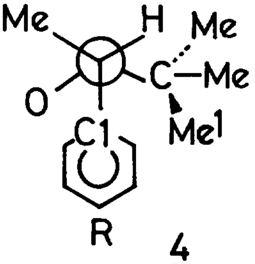

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In order to obtain the insight into the nature of the interaction, we carried out a molecular orbital calculation of a model system. Thus potential energy curves were calculated by the CNDO/2 method[14] for an approach of a methane molecule to a benzene molecule (See Fig. 6; the geometries of both molecules were held fixed.). This led to attractive potential curves. The stabilization energy was shown to be ca. 4.8kJ/mole at the maximum, the approximate distance between a methane hydrogen at this position and the plane of the benzene molecule being 2.0Å. The benzene molecule is sandwiched by two rings of the minimum potential energy curves as illustrated in Fig.6b (one of the rings is depicted). As to the nature of the interaction, we suggest that this originates from CH-pi type interaction (like well known OH-pi[15] or F-pi[16] interaction).

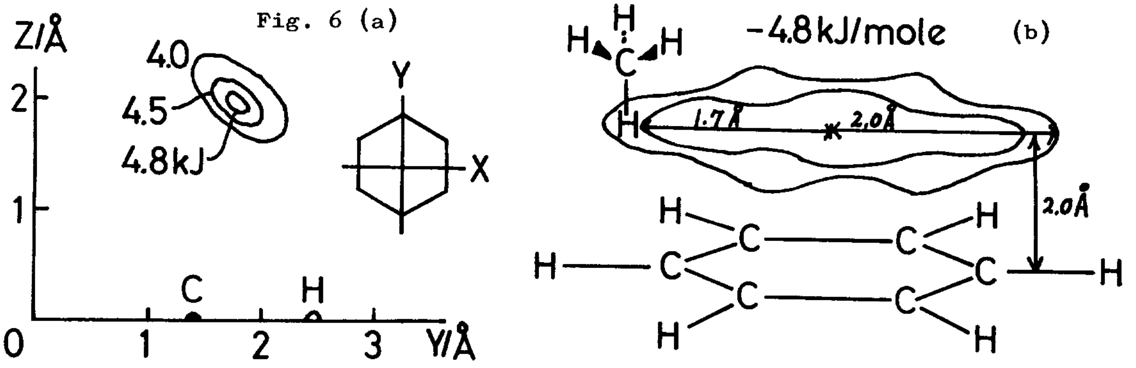
Fig. 6 (a) (b)

The magnitude of the interaction energy is relatively small, however, we believe that the interaction of this kind plays an important rôle in determining the conformations of molecules in certain systems as well as in the intermolecular interactions.[17] Current efforts are being made to the confirmation of the phenomenon and of the nature of the interaction.

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11. The Bu/Me interaction seems to play the major part in these systems.[3,7]
12. During the preparation of this paper we noticed a comment suggestive of the possible importance of an interaction of this sort. The suggestion is based on molecular mechanics calculations for 1,3,5-trineopentylbenzene system. See R.E.Carter and P.Stilbs., J.Am.Chem.Soc., 98, 7515 (1976).
13. Full accounts of the X-ray results will be reported elsewhere.
14. A CNDO/2 program was prepared by J.A.Pople, D.L.Beveridge and P.A.Dobosh (Q.C.P.E.141) and arranged by H.Kihara, T.Fujikawa and T.Aoyama. The calculations were performed at the Computer Centers in the Univ. of Tokyo and the Univ. of Electro-communications.
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17. We feel that the weak interaction of this type (CH-pi complex) plays an important rôle in determining the three dimensional structure of some biopolymers and the substrate specificities of globular proteins. Efforts are currently being made to find supports for this suggestion.