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AB INITIO AND SEMI-EMPIRICAL MOLECULAR ORBITAL CALCULATIONS ON 1,6-METHANO[10]ANNULENE[1-3]

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Since its synthesis by Vogel *et al.*,[4] 1,6-methano[10]annulene has been subjected to extensive investigation to explore its reactivity and aromaticity. We report here the results of *ab initio*, CNDO/2, and INDO molecular orbital (MO) calculations on this molecule.

The current research was undertaken to assess the reactivity and aromaticity of the molecule in relation to other ten π-electron aromatic molecules such as naphthalene and azulene.[5] Such studies will allow exploration of the role of the annulene as a substitute for the aromatic moiety in medicinal agents, and comparison of the results of the theoretical calculations with available experimental data regarding structure and reactivity.

<u>METHODS OF CALCULATION:</u> The recently developed *ab initio* technique (the molecular fragment method)[2] was used in conjunction with CNDO/2 and INDO calculations[6] for comparison.

In the molecular fragment method, the basis orbitals employed are floating spherical Gaussian orbitals.[7] The parameters for CH_4 and CH_3 fragments are those used in earlier characterizations of benzene and naphthalene isomers.[5] The geometry chosen for the molecule is that of the x-ray study of Dobler and Dunitz[8] on 1,6-methano[10]annulene-2-carboxylic acid (henceforth referred to as the non-planar geometry). For comparison, *ab initio* calculations were also performed on 1,6-methano[10]annulene with the ten ring atoms held in a planar geometry. The *ab initio* SCF calculations were carried out using double-precision arithmetic on a HW-635 computer, and convergence of the SCF procedure was assumed when the maximum absolute error in the charge and bond order matrix after the i^{th} iteration was $\leq 10^{-5}$.

RESULTS AND DISCUSSION: Figure 1 gives the MO structure as predicted by the molecular fragment method, and Figure 2 gives the charge distribution and bond orders in the 1,6-methano-[10]annulene molecule as predicted by the molecular fragment, CNDO, and INDO methods. It is interesting first to note that, in the [10]annulene (both "planar" and "non-planar"), the π-type MOs are grouped together as the upper-most filled orbitals. A similar situation is seen for *trans*-decapentaene,[9] but in azulene two σ-orbitals are interspersed among the filled π-orbitals, and in naphthalene three σ-orbitals are interspersed. Also, in anthracene and phenanthrene four σ-orbitals are interspersed.[10] However, the CNDO/2 and INDO results on 1,6-methano[10]annulene (non-planar) indicate a stabilization of the lowest π-orbital greater

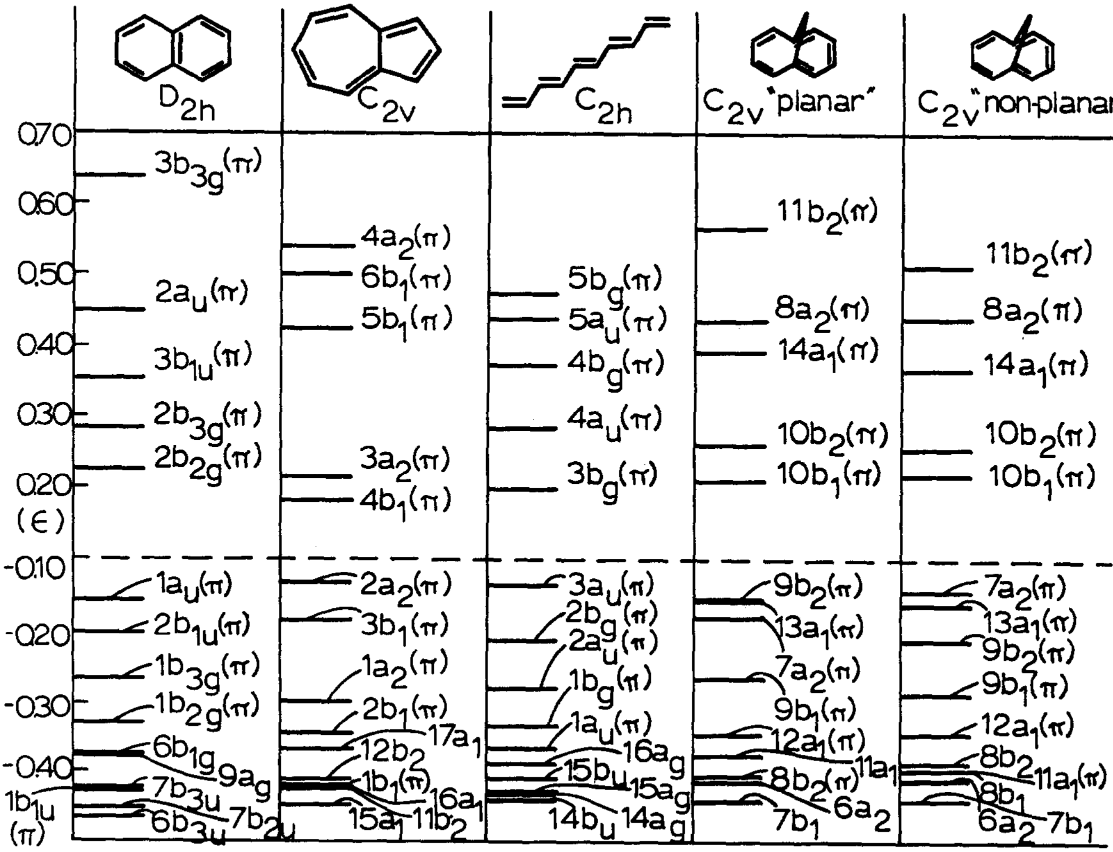

Figure 1. *Ab initio* MO structure of selected orbitals of [10]annulenes and related molecules. MO designations in the [10]annulenes are only approximate due to the lack of rigorous σ-π separation.

than observed in the *ab initio* studies, resulting in the interspersion of two σ-orbitals within the π-orbitals.

The ordering of π-MOs, obtained using the molecular fragment procedure, agrees completely with that reported by Boschi[11] *et al.*, in their photoelectron spectroscopic study. However, it contrasts sharply with the symmetry designations of Blatmann[12] *et al.*, where a D_{2h} symmetry was assumed for the molecule and Hückel MO theory was used to obtain the assignments of a_u and b_{1u} to the highest bonding orbitals. Considering the documented ability of the molecular fragment method to predict the electronic structure of molecules such as these,[2] and the tendency of CNDO and INDO to over-stabilize low-lying π-orbitals, it is believed that the valence MO structure is correctly given by the current *ab initio* study. These results indicate the annulene molecule to be of weak or intermediate aromaticity, which contrasts with the observation of a ring current in the nmr spectrum[4] that closely parallels that of aromatic molecules. However, it has been suggested[13] that ring geometry may complicate the ring-current argument in this system.

A consideration of the charge densities and bond orders of Figure 2 shows a localization of charge in the C_2-C_3, C_4-C_5, C_7-C_8, and C_9-C_{10} bonds (using any of the three methods). This is entirely consistent with the observed chemical reactivity of the molecule towards dienophiles.[4] Also, the charge distribution of the various [10]annulene carbon atoms accords well with known aromatic electrophilic substitution reactions of the molecule[4] and its reactivity

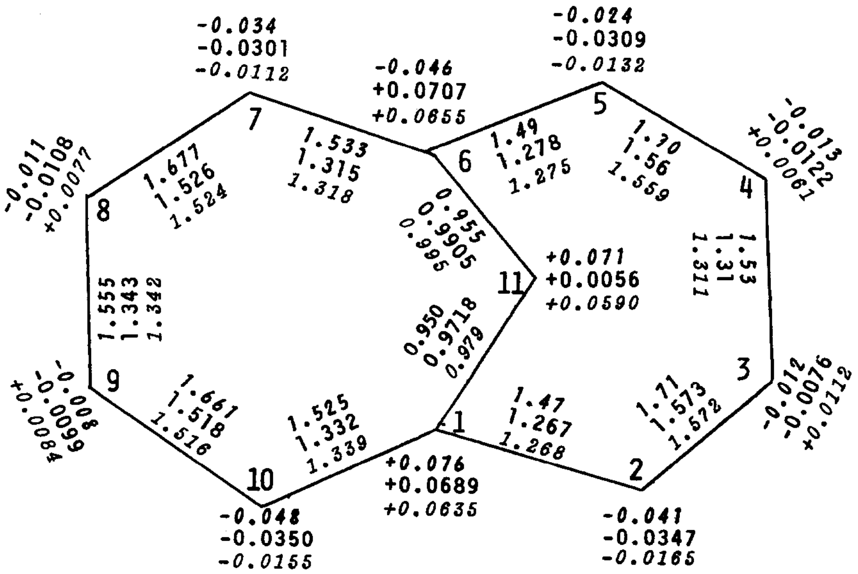

Figure 2. Charge distribution (negative values represent increased electron density) and bond orders in 1,6-methano-[10]annulene: Molecular fragment (top line), CNDO (middle line), *INDO (bottom line)*.

towards the nucleophile CH_3SOCH_2Na, where this base adds to the C_1 atom to give a homoaromatic 10 π-electron system.[14]

As a measure of aromaticity, the average π-electron energy per π-electron pair was calculated[5,10] and found to be -0.2754 (naphthalene), -0.2738 (azulene), -0.2662 (*trans*-decapentaene), -0.2284 (1,6-methano[10]annulene, non-planar geometry), and -0.2495 (1,6-methano[10]annulene, planar ring geometry). Comparisons such as these are complicated considerably, however, as incomplete σ-π separations occur in the annulenes and C_{11} has significant π-character.

In conclusion, the current study shows that, in its crystallographic conformation, the [10]annulene molecule is of weak or intermediate aromaticity, and thus would be expected to impart different transport, receptor interaction, and metabolism properties to drug molecules in which it replaces naphthalene. Studies are currently in progress to investigate these hypotheses further.

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