2 obeys the octant rule, but 1 exhibits "anti-octant" behavior in isopentane solvent.

The syntheses of 1 and 2 were accomplished in a straightforward way from 7,7-dimethoxybicyclo[2.2.1]-heptene (3).[17] Thus, oxymercuration of 3 led to a 90% yield of pure *exo*-7,7-dimethoxybicyclo[2.2.1]heptan-2-ol which was resolved *via* the half acid phthalate *l*-ephedrine salt to give the (+)-alcohol in 50% optical purity. Chromic acid oxidation of the (+)-alcohol in pyridine–dichloromethane afforded the (−)-2-ketone in 73% yield. The (−)-2-ketone was converted smoothly to its (+)-*exo*-methylene derivative in 85% yield using methyltriphenylphosphonium iodide and dimsylpotassium in dimethyl sulfoxide. Catalytic hydrogenation of the (+)-*exo*-methylene compound gave, in nearly quantitative yield, a 4:1 mixture of 1 and 2 after acid-catalyzed deketalization. The ketal mixture was separated by column chromatography or gas–liquid chromatography on Carbowax 20M. The major isomer was expected to be 1 on the basis of stereoselective catalytic hydrogenation and chromatographic behavior in which 1 is the faster moving isomer. This assignment was substantiated by the nmr chemical shift of the methyl group in 1 (d, δ 0.96 ppm) and 2 (d, δ 1.10 ppm) and the greater methyl shift of 1 with added $Eu(dpm)_3$.

The absolute configuration of both isomers could be determined from the observed (+) CE sign (Figure 1) of the endo isomer (2). Independently, (+)-*exo*-7,7-dimethoxybicyclo[2.2.1]heptan-2-ol was converted to norcamphor of known absolute configuration first by smooth deketalization–thioketalization with butanethiol and then desulfurization of the thioketal with Raney nickel to yield norborneol followed by oxidization to (1*S*)-norcamphor with a negative CE.[18]

An octant projection diagram[3] of 1 and 2 places the lone dissymmetric methyl perturber in a lower right or upper left (+) back octant. However, from an examination of the CD curves (Figure 1) corresponding to the long wavelength n–π^* carbonyl transitions, the predicted positive CE sign may be observed for 2, whereas a negative CE sign is found for 1. We believe that the apparent "anti-octant" effect exhibited by 1 should be interpreted not as an "anti-octant" effect but rather as a normal octant effect with the methyl perturber of 1 lying in a (−) *front* octant. Such a rationale would explain other so-named "anti-octant" effects for alkyl and perhaps other perturbers, and it would clearly require the third, nonsymmetry derived, octant-defining surface to be nonplanar.[3] In this connection, it should be noted that this surface was only approximated as a plane[19] for lack of more exact experimental information. In theory, its precise contour and placement should be defined for each different type of perturber, *e.g.*, alkyl *vs.* halogen. The concept presented here is further reinforced by our CD data on a completely unambiguous front octant compound of known absolute configuration, (1′*S*)-spiro[cyclobutan-2-one-1,4′-(2(*R*)-methyladamantane)], which exhibits the expected negative CE[20] due to the lone CH_3 perturber lying *in front of the carbonyl oxygen.*

(17) P. G. Gassman and J. Marshall, *Org. Syn.*, **48**, 68 (1968).
(18) K. Mislow and J. G. Berger, *J. Amer. Chem. Soc.*, **84**, 1956 (1962).
(19) See footnotes 4 and 17 of ref 3 which refer to the *XY* plane.
(20) D. A. Lightner and T. C. Chang, manuscript in preparation.

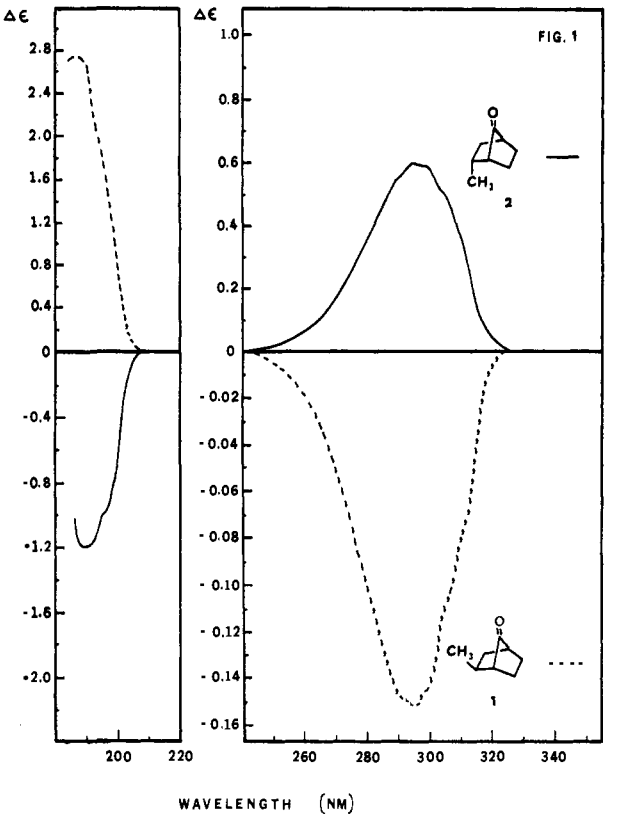

Figure 1. Circular dichroism spectra of (1*R*)-*exo*-2-methylbicyclo[2.2.1]heptan-7-one (1) (- - -) and (1*R*)-*endo*-2-methylbicyclo-[2.2.1]heptan-7-one (2) (—) in isopentane at 20°. Measured on a JASCO J-20 ORD-CD spectrometer with photoelastic modulator. Corrections are made to 100% optical purity.

Although the locations of the methyl groups are very different, the magnitudes of the n–π^* CE's of 1 ($\Delta\epsilon_{max}$ = −0.15, isopentane) and 2 ($\Delta\epsilon_{max}$ = +0.60, isopentane) are roughly equal. These may be compared to Snatzke's 3-axial ($\Delta\epsilon_{max}$ = +0.052, isooctane; −0.093, dioxane) and 3-equatorial ($\Delta\epsilon_{max}$ = +0.57, isooctane) methyl adamantanones in the same absolute configuration series, of which the former exhibits slightly weaker magnitudes and a critical and peculiar solvent dependence. Our current instrumentation allows us to measure the short-wavelength CE's of 1 and 2 (Figure 1) in the vicinity of 190 nm.

(21) Petroleum Research Fund Postdoctoral Fellow, 1973–1974.

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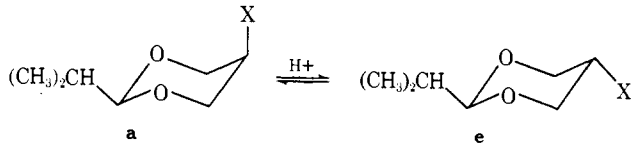
Acetylcholine Analogs. Conformational Equilibria Dominated by Electrostatic Interactions

Sir:

In a previous publication[1] we had pointed out that, whereas in a 5-thiomethyl-1,3-dioxane (Table I, 1) the equatorial isomer (**1e**) predominates at equilibrium by over 1 kcal/mol, the position of equilibrium is shifted toward the axial isomers (**2a**, **3a**) in the cases of the

(1) E. L. Eliel and S. A. Evans, Jr., *J. Amer. Chem. Soc.*, **94**, 8587 (1972).

Table I



a e

Compound	X	$\Delta G°$, kcal/mol	Solvent
1	CH_3S	−1.13; −1.20; −0.90	CH_3CN; $CHCl_2COOH$; CF_3COOH
2	CH_3SO	0.86	CH_3CN
3	CH_3SO_2	1.19	$CHCl_3$
4	$(CH_3)_2S^+$	>2	$CHCl_2COOH$ or CF_3COOH
5	NH_3^+	3.14 ± 0.15	$CHCl_3$–CF_3COOH
6	$NH(CH_3)_2^+$	>2	C_6H_5CN–CF_3COOH
7	$N(CH_3)_3^+$	2.01 ± 0.10	$CHCl_2COOH$

corresponding sulfoxides and sulfones ($\Delta G° \sim +0.9$ and +1.2 kcal/mol, respectively). Moreover, in the case of the axial sulfone (**3a**), the methyl group is turned inside the ring and the oxygens are on the outside.

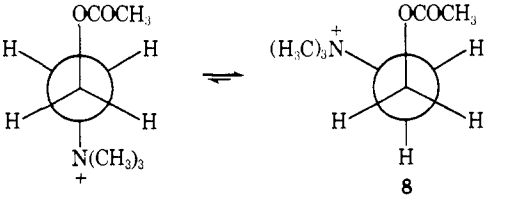
Three explanations are possible. (1) The axial preference of the sulfoxide and sulfone functions is caused by the greater accessibility of their d orbitals, stabilization being caused by overlap of the unshared p electrons of oxygen with an empty d orbital on sulfur. (2) The dominant force is an electrostatic attraction between ring oxygens (sites of negative charge) and the exocyclic sulfur (a site of positive charge in the sulfoxide and sulfone but not in the sulfide). (3) Hydrogen bonding between the *S*-methyl group and the ring oxygen atoms stabilizes the axial isomer when the sulfur is positively charged (as in **2a** and **3a**).

To reach a decision between explanation (1) as against (2) or (3), we have now synthesized and equilibrated the dimethylsulfonium salts, **4**, and the ammonium salts, *N*,*N*-dimethylammonium salts, and trimethylammonium salts **5** and **6** and **7**.[2] Equilibration was carried out with trifluoroacetic acid or dichloroacetic acid[7] starting with initially trans-rich (**e**) or cis-rich (**a**) mixtures. Products were analyzed by proton nmr (using the *N*-methyl or *S*-methyl signals) in the case of **4**, **6**, and **7** and by gas chromatography (after liberation of free amines by base) in the case of **5**. The results are shown in Table I. In the case of **4** and **6**, the signals for **4e** and **6e** could not be seen; control experiments show that as little as 3% of the equatorial isomer (corresponding to $\Delta G° = 2$ kcal/mol) could have been found, and this value is thus taken as the lower limit for $\Delta G°$ in these two cases.

It is clear (Table I) that a strong axial preference is found for the ammonium salts (**5**, **6**, **7**) as well as for the sulfonium salts (**4**). Since d orbitals in ammonium salts are too high in energy to be accessible, electrostatic interactions must be responsible for the axial preference in these compounds and therefore presumably also for the analogous preference in the sulfur compounds **2**, **3**, and **4**.

The results are of particular interest since they bear on the question of conformation of acetylcholine, **8** (Scheme I). X-Ray data,[8] nmr studies,[9] and quantum

Scheme I



8

mechanical calculations[10] indicate acetylcholine to be in the gauche form; however, the X-ray studies refer to the solid state and the nmr data provide somewhat indirect evidence because of fast rotation about the C_1–C_2 bond. In our model compounds, **5**–**7**, the highly mobile conformational equilibrium of **8** is replaced by a chemical equilibrium (the axial isomer corresponding to the gauche and the equatorial to the anti form) which can be studied with greater confidence.

In the case of **8** it has been claimed, on the basis of calculation,[10b] that a substantial contributing factor to the stability of the gauche form is hydrogen bonding between the acetate oxygen (Ac*O*) and the *N*-methyl hydrogens [$N^+(CH_3)_3$]. Our compounds **2** and **4** provide suitable models to study this point. If hydrogen bonding is important, the methyl groups of **2** and **4** should point into the ring, but, if the force stabilizing **2a** and **4a** is strictly electrostatic and the Me/O interaction actually repulsive, **2a** and **4a** should have the sulfur lone pairs facing inside the ring with the methyl groups being outside.[11] While we are still pursuing the evidence in this regard, preliminary findings suggest **2a** to exist with the methyl group outside; we were unable to resolve any long-range coupling for this group (in the case of **3a**, $^4J_{Me/H\text{-}5} = 1.4$ Hz, *i.e.*, readily resolvable). In this context, it would seem significant that in the axial tertiary carbinol, Table I, **a**, X = $(CH_3)_2COH$ where the OH group is in fact forced into the ring, infrared studies[12] have indicated that little

(2) Compounds **4** (as tosylates) were synthesized from the corresponding sulfides[1] (**1a**, **1e**) and methyl *p*-toluenesulfonate. The amine corresponding to **5** was synthesized from the corresponding nitro compound[3-5] by hydrogenation over Pd(C); the diastereoisomers **5a** and **5e** were separated by gas chromatography on a 12 ft × 3/8 in. 20% Carbowax, 10% KOH column (Chromosorb A, 60–80 mesh), at 150°. The dimethyl compounds **6a** and **6e** were synthesized from **5a** and **5e** by methylation with formaldehyde and sodium cyanoborohydride[6] and were converted to and used as the corresponding picrates, mp 153–154° (**6a**) and 180–181° (**6e**). The quaternary methiodides **7a**, mp 203–204°, and **7e**, mp 181–182°, were prepared from the amines **5a** and **5e** by methylation with methyl iodide and potassium carbonate. All compounds gave satisfactory elemental analyses.

(3) E. L. Eliel and M. K. Kaloustian, *Chem. Commun.*, 290 (1970).

(4) M. K. Kaloustian, Ph.D. Dissertation, University of Notre Dame, Notre Dame, Ind., 1970.

(5) See also E. L. Eliel and R. M. Enanoza, *J. Amer. Chem. Soc.*, **94**, 8072 (1972). The configurational assignment of the amines is further supported by dipole measurement of the precursor cis nitro compound (Table I, **a**, X = NO_2; $\mu = 4.57$ D) (calcd for equatorial NO_2, 1.85 D, for axial NO_2, 4.84 D).[4]

(6) R. F. Borch and A. I. Hassid, *J. Org. Chem.*, **37**, 1673 (1972).

(7) In repeating previous equilibrations in these media we find that $\Delta G°$ for **1** in $CHCl_2COOH$ (−1.20 kcal/mol) is similar to that in the CH_3CN (−1.13 kcal/mol[1]) whereas the more polar trifluoroacetic acid favors **1e** slightly less ($\Delta G° = -0.9$ kcal/mol).

(8) F. G. Canepa, P. Pauling, and H. Sörum, *Nature (London)*, **210**, 907 (1966); J. K. Herdklotz and R. L. Sass, *Biochem. Biophys. Res. Commun.*, **40**, 583 (1970); see also B. Jensen, *Acta Chem. Scand.*, **24**, 2517 (1970), regarding succinylcholine, and M. Sundaralingham, *Nature (London)*, **217**, 35 (1968), for a general discussion.

(9) C. C. J. Culvenor and N. S. Ham, *Chem. Commun.*, 537 (1966).

(10) (a) G. N. J. Port and A. Pullman, *J. Amer. Chem. Soc.*, **95**, 4059 (1973); (b) D. L. Beveridge and R. J. Radna, *ibid.*, **93**, 3759 (1971).

(11) No conclusions can be drawn from the fact that **3a** exists with the methyl group inside the ring,[1] for in the alternative conformation O^- would have to point inside, generating electrostatic repulsion with the ring oxygens.

(12) E. L. Eliel and H. D. Banks, *J. Amer. Chem. Soc.*, **94**, 171 (1972).

intramolecular bonding occurs, the H of the OH group pointing away from rather than toward the ring oxygens, and in the corresponding primary alcohol (Table I, **a**, X = CH_2OH), even though the axial isomer is energetically preferred,[4] no hydrogen bonding occurs at all.[12] In conclusion, it appears that the axial preference in compounds **2–4** and **7** rests largely if not entirely on electrostatic grounds;[13] by inference, the same is probably true for acetylcholine (**8**).[14]

(13) Hydrogen bonding of the N^+–H moiety may cause the additional axial preference in **5** and **6** as compared to **7**.

(14) The implication that hydrogen bonding is unimportant in acetylcholine agrees with the conclusions, based on X-ray data, by J. Donahue in "Structural Chemistry and Molecular Biology," A. Rich and N. Davidson, Ed., W. H. Freeman, Co., San Francisco, Calif., 1968, p 459 ff.

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Crystal Structure and Autoreactivity of the Diphenyl(phenylethynyl)aluminum Dimer. A Model for π-Complexation between Alkynes and Organoaluminum Compounds[1]

Sir:

The ease with which aluminum alkyls and alkylaluminum hydrides add to carbon–carbon unsaturation has been ascribed to the electron deficiency of unsolvated tricoordinate aluminum,[2] a conjecture subsequently borne out by the sharply reduced reactivity of organoaluminum etherate and aminate complexes in such additions[3–5] and by kinetic measurements of carbalumination[5–8] and hydralumination.[9] The observed kinetic orders require that the originally dimeric aluminum alkyl or trimeric dialkylaluminum hydride dissociate into monomeric, tricoordinate aluminum before reacting with carbon–carbon unsaturation.

As to the electronic demands of these reactions, Hammett studies of the carbalumination of para-substituted diphenylacetylenes[4,5] and of 6-substituted benzonorbornadienes[8] have shown that the reaction has a modest, but negative, ρ value (-0.6 to -0.8) consistent with electrophilic attack by tricoordinate aluminum on carbon but with little charge separation in the transition state (**1**). However, organoaluminum reagents add more readily to acetylenic than to olefinic

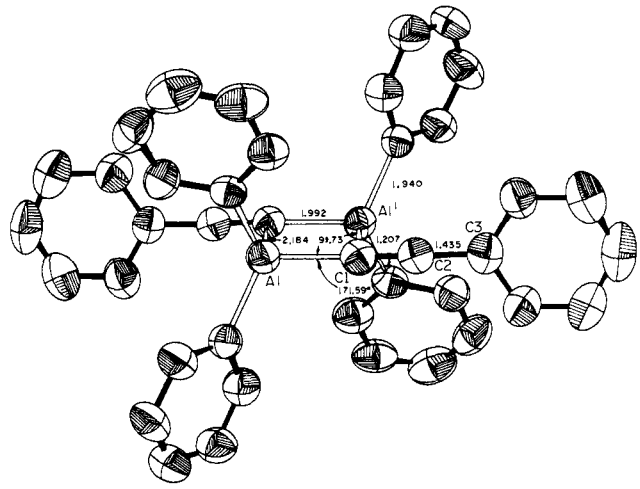
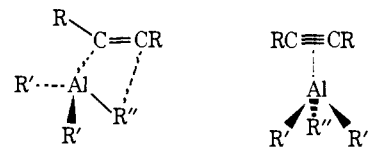


Figure 1. Molecular structure of the diphenyl(phenylethynyl)-aluminum dimer.



1, R'' = H,R' 2, R'' = H,R'

linkages,[8,10,11] in contrast with the reactivity order observed in most electrophilic additions.[12] Accordingly, these electronic characteristics, together with the stereochemistry observed in the hydralumination[11,13] and oligomerization[13,14] of alkynes, have led to the postulation of a π-complex intermediate (**2**).[14] But, up to the present, only indirect evidence for such π-complexes has been presented.[15]

We now wish to report that a crystal structural analysis and chemical study of the diphenyl(phenylethynyl)-aluminum dimer (**3**)[16,17] provides strong support for the existence of π-complexation between aluminum and the acetylenic group (Figure 1). Nuclear magnetic resonance spectral studies of dimeric dimethyl(phenylethynyl)aluminum and its exchange processes with trimethylaluminum or dimethyl(phenyl)aluminum have already led to the suggestion that the phenylethynyl group is the preferred bridging group,[18] but it was surmised that the bridging group would be perpendicular to the Al–Al axis and possess allenic character (**4**). The recently reported crystal structure of dimeric methyl(1-propynyl)beryllium trimethylamine, with bridging propynyl groups and Be—C≡C angles of 147 and 136°, respectively, appeared to offer a close precedent for this type of bridging.[19]

(1) This is a continuation of two series of studies, "Organometallic Compounds of Group III," contribution XXV, devoted to carbometallation and hydrometallation, and "The Stereochemistry of Polynuclear Compounds of the Main Group Elements." For previous papers, see J. J. Eisch and G. R. Husk, *J. Organometal. Chem.*, **64**, 41 (1974); and R. Zerger and G. D. Stucky, *Chem. Commun.*, 44 (1973), respectively.

(2) R. Robinson, *Chem. Age*, **74**, 997 (1956).

(3) K. Ziegler, F. Krupp, K. Weyer, and W. Larbig, *Justus Liebigs Ann. Chem.*, **629**, 251 (1960).

(4) J. J. Eisch and C. K. Hordis, *J. Amer. Chem. Soc.*, **93**, 2974 (1971).

(5) J. J. Eisch and C. K. Hordis, *J. Amer. Chem. Soc.*, **93**, 4496 (1971).

(6) K. Ziegler and H. Hoberg, *Chem. Ber.*, **93**, 2938 (1960).

(7) J. N. Hay, P. G. Hooper, and J. C. Robb, *Trans. Faraday Soc.*, **66**, 2045 (1970).

(8) N. E. Burlinson, Doctoral Dissertation, The Catholic University of America, Washington, D. C., May 1972.

(9) J. J. Eisch and S. G. Rhee, *J. Organometal. Chem.*, **31**, C49 (1971).

(10) G. Wilke and H. Müller, *Justus Liebigs Ann. Chem.*, **629**, 222 (1960).

(11) J. J. Eisch and M. W. Foxton, *J. Org. Chem.*, **36**, 3520 (1971).

(12) K. Yates, G. H. Schmid, T. W. Regulski, D. G. Garratt, H.-W. Leung, and R. McDonald, *J. Amer. Chem. Soc.*, **95**, 160 (1973).

(13) J. J. Eisch and R. Amtmann, *J. Org. Chem.*, **37**, 3410 (1972).

(14) J. J. Eisch, R. Amtmann, and M. W. Foxton, *J. Organometal. Chem.*, **16**, P55 (1969).

(15) (a) J. J. Eisch and W. C. Kaska, *J. Amer. Chem. Soc.*, **88**, 2213 (1966); (b) S. G. Rhee, Doctoral Dissertation, The Catholic University of America, Washington, D. C., May 1972.

(16) J. J. Eisch and W. C. Kaska, *J. Organometal. Chem.*, **2**, 184 (1964).

(17) T. Mole and J. R. Surtees, *Aust. J. Chem.*, **17**, 1229 (1964).

(18) (a) E. A. Jeffery, T. Mole, and J. K. Saunders, *Aust. J. Chem.*, **21**, 137 (1968); (b) N. S. Ham, E. A. Jeffery, and T. Mole, *ibid.*, **21**, 2687 (1968).

(19) B. Morosin and J. Howatson, *J. Organometal. Chem.*, **29**, 7 (1971).