Table I. Absolute Distribution Coefficients for Transfer from Dilute Aqueous Solution to the Vapor Phase at 25 °C[a]

Ethane[b]	22
Ethylene[b]	9.6
Acetylene[b]	1.1
Dimethyl ether[c]	4.1×10^{-2}
Ethyl acetate[d]	5.4×10^{-3}
Acetone[d]	1.3×10^{-3}
Ethylamine[d]	4.1×10^{-4}
Ethanol[e]	2.1×10^{-4}
Acetic acid[f]	1.1×10^{-5}
Acetamide[f]	7.6×10^{-8}
Ammonia[g]	7.7×10^{-4}
Water[h]	2.5×10^{-5}

[a] Equilibria in mol/l. in vapor, divided by mol/l. in dilute aqueous solution. [b] Reference 8. [c] Reference 9. [d] Reference 10. [e] Reference 1. [f] This work. [g] Reference 11. [h] Reference 12.

Table II. Free Energies of Reaction in Dilute Solution and in the Vapor Phase

	Acetamide hydrolysis	Ethyl acetate hydrolysis	Ethyl acetate ammonolysis
ΔG for reaction in dilute aqueous solution at 25 °C[a]	+6.4[c]	+0.7[d]	−5.7
(ΔG for solvation of gaseous products) − (ΔG for solvation of gaseous reactants)[b]	+4.9	−2.4	−7.3
ΔG for reaction in the dilute vapor phase at 25 °C	+1.5	+3.1	+1.6

[a] Free energies in kcal based on uncharged reactants and products in dilute solution, with water activity taken as 55.6 M. [b] Free energies of solvation calculated from distribution coefficients in Table I. [c] Assumed equivalent to a value for propionamide, calculated from the data of Morawetz and Otaki using propionic acid $pK_a = 4.88$ (ref 14). [d] Reference 15.

terminations.[6] Values for simple representatives[7] of organic compounds of various classes, compared in Table I, are distributed over a range that exceeds eight orders of magnitude. The extreme position of acetamide is consistent with a relatively large shift in carbonyl stretching frequency that occurs when the compound is transferred to water from the vapor phase,[13] and with the possibility that the molecule in aqueous solution possesses some zwitterionic character.

Theoretical considerations suggest[16,17] that noncovalent hydration often plays a decisive role in determining biochemical energetics in aqueous solution. This is illustrated clearly by the equilibria for hydrolysis of amides and esters, which are actually shifted in opposite directions when these reactions are transferred between dilute aqueous solution and the vapor phase (Table II). This effect is so pronounced that solvation may be said to provide the entire driving force (−7.3 kcal) for the ammonolysis of ethyl acetate, a reaction which is strongly exergonic in water but slightly endergonic in the vapor phase (Table II). There is little doubt that changing solvation exerts an important influence on the equilibrium conformation of macromolecules, the catalytic activity of enzymes, and the behavior of biological receptors and energy transducing systems. It would therefore be useful to have information about the solvation of other polar molecules of biological interest.

Acknowledgment. The author would like to thank Drs. M. Bursey and M. Caplow for mass spectrometric measurements, which established an upper limit for the partial pressure of aqueous acetamide, and Dr. J. H. Wolfenden for encouragement and incisive criticism. He is grateful to the National Institutes of Health for a research grant (GM-18325) and a research career development award (AM-08560).

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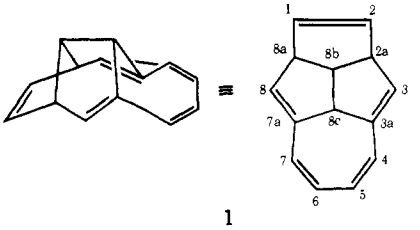
2a,8a,8b,8c-Tetrahydropentaleno[6,1,2-*aji*]azulene

Sir:

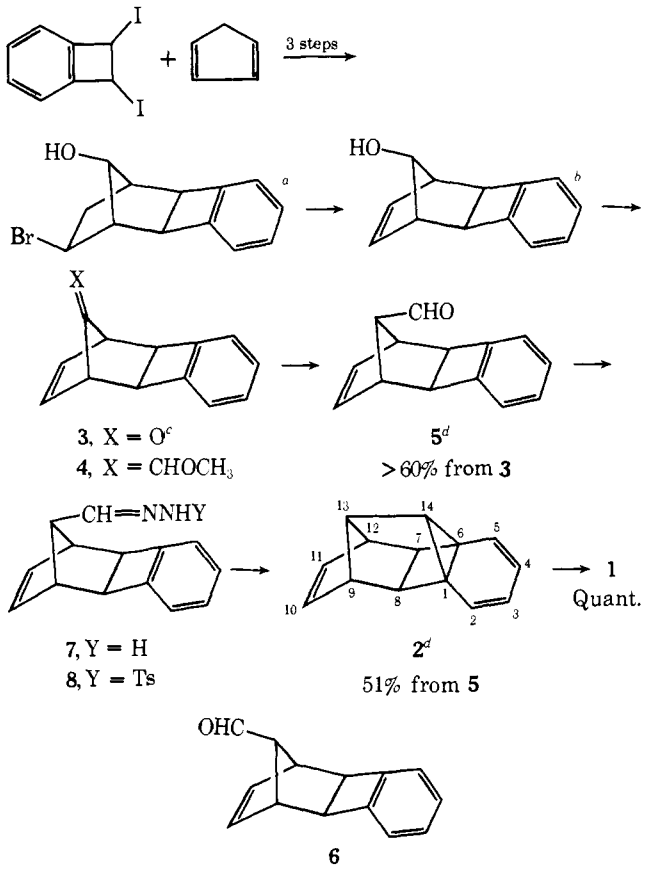
The triquinacenes have stimulated great interest for both theoretical and synthetic chemists.[1-3] A new member of this fascinating family of compounds, 2a,8a,8b,8c-tetrahydropentaleno[6,1,2-*aji*]azulene (**1**), has special significance because of its relationship to potentially antiaromatic [12]annulenes.[4] We wish to report the synthesis of **1**, which involves a new approach to the triquinacene system and which employs an unusually facile formal $_{\sigma}2_S + {}_{\sigma}2_S$ cycloreversion.



1

The synthetic path recognizes the relationship between **1** and norcaradiene **2** and is outlined in Scheme I. The ketone **3** is readily available by an amalgamation of the work of Baker[5] and Battiste.[6] Subjection of ketone **3** to condensation with the preformed methoxy Wittig reagent ($Ph_3P^+CH_2OCH_3Cl^-$, n-C_4H_9Li, THF) under forcing conditions (diglyme, room temp → reflux) gave the desired enol ether **4**[7] [NMR: δ 5.04 (s, 1 H), and 3.02 (s, 3 H); ir 1730 (=OCH_3), 1603 (aryl) cm^{-1}], which, without purification, was treated with 3 N aqueous hydrochloric acid at room temperature to smoothly give the desired aldehyde **5**,[7] mp 74–7 °C [NMR: δ 8.34 (s, 1 H), 6.8–7.2 (AA′BB′, 4 H), 6.29 (t (J = 2 Hz), 2 H), 3.35 (br s, 2 H), 3.22 (s, 2 H),

Scheme I. Synthesis of 2a,8a,8b,8c-Tetrahydropentaleno[6,1,2-*aji*]azulene (1)



[a] Mp 114.8–115.0 °C. [b] Mp 91.2–91.8 °C. [c] Mp 130.0–131.2 °C. [d] For melting point see text.

2.15 (s, 1 H); ir 2720, 1710, 1595 cm^{-1}]. The stereochemistry of the aldehyde group as syn was established by comparison to the anti isomer **6**[7,8] synthesized independently, as well as the ultimate success of the intramolecular insertion to form **2**. In particular, the aldehydic proton at δ 9.55 and its α proton at δ 1.89 in **6** may be contrasted with the corresponding absorptions in **5** indicating the proximity of the aldehyde and the benzene ring in the latter.

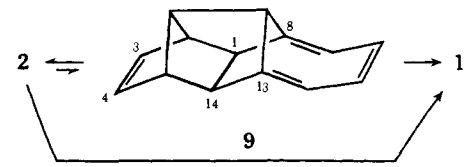
Conversion of **5** to its hydrazone **7** which, without purification, was subjected to yellow mercuric oxide[9] in benzene containing a 3 M ethanolic potassium hydroxide solution (21:1 v/v) at 40° for 16 h gave directly the desired hexacyclo[6.6.0.$0^{1,6}$.$0^{6,14}$.$0^{7,12}$.$0^{9,13}$]tetradeca-2,4,10-triene (**2**),[7] mp 93.2–95.0 °C [NMR δ 5.98 (AA′ part) and 5.58 (BB′ part of AA′BB′ system, 4 H), 5.54 (t (J = 3.5 Hz), 2 H), 3.39 (m, 1 H), 3.03 (br s, 2 H), 2.30 (s, 2 H), 0.08 (d (J = 4 Hz), 1 H); uv λ_{max}, nm (ϵ), 275 (3700), 210 (8200)]. The uniqueness of this direct oxidative insertion is underscored by the failure of various salts including mercuric oxide to catalyze efficiently the insertion of the preformed diazo compound. The existence in the norcaradiene form is indicated by the high field position of the proton at C-14 and comparison of the uv data to other norcaradienes.[10] ^{13}C NMR shows three types of vinyl carbon [δ 129.7 (d, J = 167.4, C-10,11), 122.4 (d, J = 161.8), 120.1 (d, J = 156.2)], three types of simple saturated carbon [δ 65.7 (d, J = 146.1, C-13), 56.9 (d, J = 145.7, C-9,12), 49.1 (d, J = 154.4, C-7,8)], and two types of cyclopropyl carbon [δ 48.8 (s, C-1,6), 26.8 (d, J = 175.7, C-14)], and confirms the assigned structure. No evidence for the cycloheptatriene form exists.

Completion of the synthesis requires a formal $_{\sigma}2s + _{\sigma}2s$ cycloreversion and was initially attempted at high temperature. Surprisingly, systematic temperature variation indicated that complete conversion to pure **1**[7] was achieved at 145° in less than 7 min ($k \sim 1.7 \times 10^{-3}$ s^{-1}) in degassed diglyme. Decomposition of the tosylhydrazone **8** [NaH, diglyme, 145–150 °C] led directly to **1**; however, the reaction product was not as clean as that produced from **2**. Pentaene **1** was unstable; it decomposed on storage at −20°, even in solution, after a few days.

The structure of **1** was supported by its spectroscopic data [NMR AA′BB′ pattern at δ 6.4 and 5.8 (4 H), 5.50, (br s, 2 H), 5.40 (s, 2 H), 4.08 (dt (J = 10,8 Hz)), 3.82, (br d (J = 10 Hz), 1 H), 3.76 (dd, J = 8,2 Hz, 2 H); uv λ_{max}, nm (ϵ), 349 (4500), 323 (4200)]. The ^{13}C NMR spectrum was most informative [δ 142.2 (s, C-3a,7a), 130.4 (d (J = 164.6), C-1,2 or C-3,8), 129.9 (d (J = 161.8), C-1,2 or C-3,8), 129.1 (d (J = 158.1), C-4,7), 125.0 (d (J = 152.6), C-5,6), 57.2 (d (J = 134), C-2a,8a), 56.8 (d (J = 134), C-8c), 49.0 (d (J = 133), C-8b)]. Assignments are based upon comparison to triquinacene,[11] selective proton decoupling, and line shape criteria.[12]

The existence of homoaromaticity or other unusual electronic properties is difficult to ascertain. For example, the bathochromic shift relative to 5,7-bismethylenecyclohepta-1,3-diene[13] may arise, in part, from interaction of this unit with the additional double bond in **1**. However, the magnetic properties do not reveal the presence of a diamagnetic ring current.

On the other hand, the unusual facility of the isomerization of **2** to **1** is striking, especially in view of the fact that decompositions of substituted bicyclo[2.1.0]hexanes have been reported to have $t_{1/2} > 20$ h at 200°.[14] Whether **2** or its isomer, **9**, is the immediate precursor to **1**, concerted opening is a symmetry-forbidden process. Bishomoconjugative stabilization of the transition state by the C-3, C-4 double bond in **9** may be a possible explanation even though the results of Frey et al.[15] on the bicyclo[4.2.1.$0^{2,5}$]nona-3,7-diene system open such an interpretation to question. Uncertainties in evaluating the strain released in the transition state in going from **2** or **9** to **1** make an estimation of the activation energy of the nonconcerted diradical process of approximately 10 kcal higher than observed subject to a large error.[16] However, in our opinion, this difference is sufficiently large that additional factors, such as subjacent orbital control[19] and bishomoaromatic stabilization of the transition state, among others, must be considered.



Acknowledgment. We wish to thank the National Science Foundation and the National Institutes of Health for their generous support of our programs.

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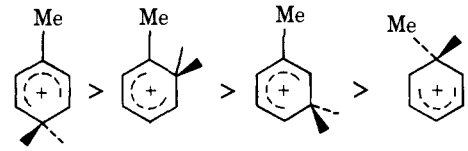
The Proton Affinities of Toluene

Sir:

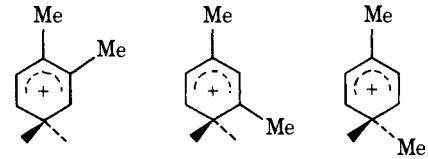
There are, at least count, four likely alternatives for the structure of protonated toluene. In addition to those geometries in which the proton has associated itself with the ring carbons ortho, meta, or para to the methyl, there is the possibility of protonation directly at the site to which the alkyl group is affixed to the ring. Protonation in the center of a carbon–carbon bond or directly above the aromatic ring seems unlikely in light of previous investigations.[2] In superacid media, toluene appears to protonate preferentially para to the methyl.[3] At temperatures below −97 °C, the NMR data are consistent with this being the only form present; as the temperature is raised the chemical shifts for the ring protons coalesce into a single line, indicative of rapid equilibration among the possible ions. The activation energy of such a process, presumably proton rather than methyl migration,[4] has been estimated by the temperature dependence of the ^{13}C spectrum to be 10 ± 1 kcal/mol.

In this communication, we apply experimental pulsed ion cyclotron resonance (ICR) spectroscopy[5] and ab initio molecular orbital theory[6] in an attempt to assign which of these four (most likely) structures is closest to the true ground state geometry of protonated toluene in the gas phase, and, in addition, to provide estimates of the relative stabilities of the remaining (unobserved) positional isomers. Assuming, as we shall demonstrate, that methyl substituent effects are approximately additive, such a tabulation should enable us to calculate the proton affinities of more highly alkylated benzenes. The ICR experiment alone, of course, provides no indication whatsoever as to the geometrical structure of an ion under investigation. Only its mass is subject to characterization. Furthermore it is not even possible to ascertain whether the spectrum observed in an ICR spectrometer is due to a single ion or to an equilibrium collection of two or more positional isomers. In actual practice, if the relative energies of such isomers are separated by more than a few kilocalories per mole, only the most stable ion will be present after several hundred milliseconds in a large enough concentration to be detectable.

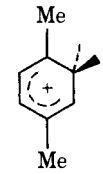
We shall start by assuming the following ordering of stabilities for the four isomers of ring protonated toluene. This is as suggested by quantitative ab initio molecular orbital calculations at the minimal basis STO-3G level. Actual the-



oretical values for the four toluene proton affinities (relative to that in benzene) as well as the single experimental energy[10] (assumed to correspond to protonation para to the methyl) are presented in Table I. Using theoretical values for all four toluene affinities, and assuming that the effects of methyl substituents on the protonation energy of benzene are additive, it is possible to assign least energy structures to the protonated xylenes.[12] The same set of structures are



also predicted by direct calculation (Table I) although for para xylene the sole alternative form appears to be of approximately equal stability. It should be emphasized that



the numerical values of the xylene proton affinities arrived at by the simple additivity relationship are nearly identical with those obtained by direct calculation.

Relative proton affinities for the isomeric xylenes have also been determined by ICR spectroscopy and are also presented in Table I. Again assuming additivity of methyl substituent effects, these data enable us to arrive at approximate experimental values for the energies of protonation of toluene, ortho, meta, and ipso to the alkyl group. Thus, subtracting the relative proton affinity of toluene from that of *m*-xylene leads to an experimental estimate of 6.0 kcal/mol for the effect of an ortho methyl substituent on the proton affinity of benzene. Such a value is in reasonable agreement with the calculated relative affinity of 6.5 kcal/mol. Correspondingly, the difference in proton affinities between *o*-xylene and toluene (2.4 kcal/mol) is a measure of the far smaller energetic effect of a methyl group meta to the site