Azulenic novel π-electronic compounds

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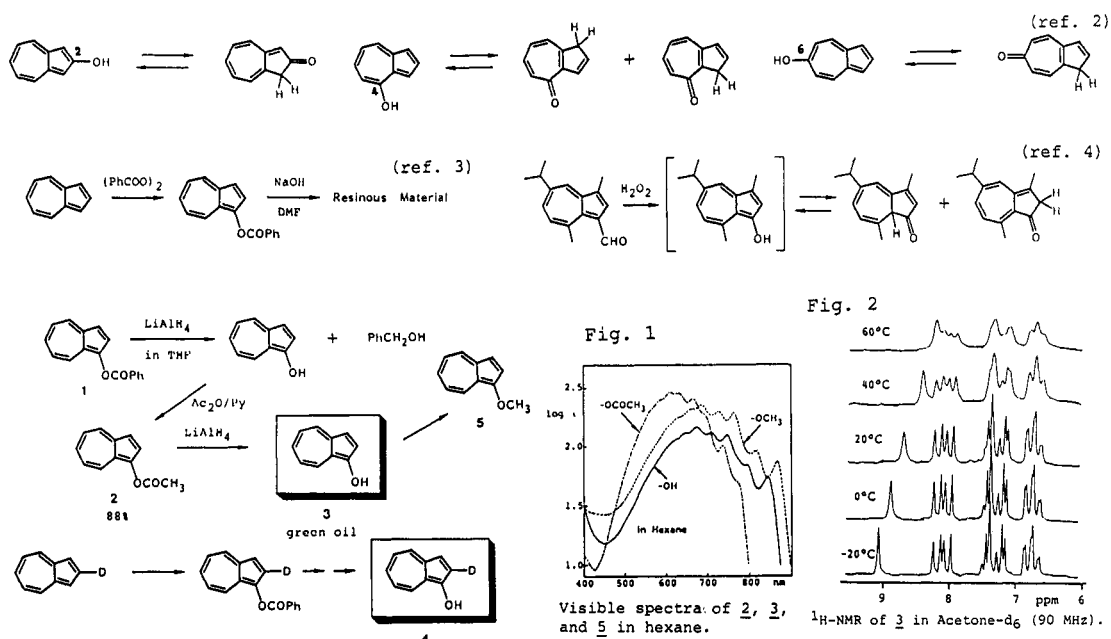Tohoku University, Kawauchi, Aoba-ku, Sendai 980 Japan

Abstract - 1) 1-Hydroxyazulene, 3-hydroxyguaiazulene, and 1-, 2-, and 6-azulenethiols were synthesized and characterized, and some chemical and spectroscopic properties were studied. 2) Diazulenyl ketone, thioketone and their derivatives, and novel π-electronic compounds such as diazuleno-pyridine and hydroxyazulylydeneazulanone were synthesized. 3) tri-(1-azulenyl)methyl carbocation and its 3-methyl and 3-methoxycarbonyl derivatives were synthesized. They showed high pK_R^+ value (around 11), and were found to exist as an equilibrium between two conformational structures.

The chemistry of azulene including synthesis, physical and chemical properties has been extensively studied for more than three decades (ref. 1). The most characteristic features of azulenes is the contribution of dipolar structure to the ground state. It has been clarified that functional groups attached to azulene showed different properties compared to those attached to benzenoid compounds. In this paper, we will describe the synthesis and some properties of newly functionalized azulenes and azulenic novel π-electronic compounds.

1 Syntheses and properties of 1-hydroxyazulene, 3-hydroxyguaiazulene and 1-, 2- and 6-azulenethiols

2-, 4-, and 6-hydroxyazulenes; isomers of naphthol, have been reported to exist in their tautomeric forms (ref. 2), depending on the solvent used. Attempted synthesis of 1-hydroxyazulene from 1-benzoyloxyazulene (1) by hydrolysis afforded only resinous subs⁺ance (ref. 3). Chiurdoglu and Fuks (ref. 4) have reported that an inseparable mixture of two kinds of keto forms of 3-hydroxyguaiazulene were obtained, however, we have been doubtful for the structure of the compounds.

Reduction of 1-benzoyloxyazulene (1) (ref. 3) with LiAlH₄ afforded an unseparable mixture of unstable green oil and benzylalcohol. Acetylation of the products yielded 1-acetoxyazulene (2), whose reduction with LiAlH₄ afforded pure 1-hydroxyazulene (3), after working up under low temperature, as green oil in quantitative yield. The compound (3) is considerably stable at -30°C, but easily polymerized at room temperature and no ketonic compound was obtained. 1-Hydroxy-2-deuteroazulene (4) was also obtained starting from 2-deuteroazulene. Visible absorption spectra (Fig. 1) of (2, 3) and 3-methoxyazulene (5), which showed a similar pattern, as well as ¹H-NMR spectra including variable temperature spectra (Fig. 2) indicate that the

(ref. 2)

(ref. 3)

(ref. 4)

Fig. 1

Visible spectra of 2, 3, and 5 in hexane.

Fig. 2

¹H-NMR of 3 in Acetone-d₆ (90 MHz).

compound (3) exists as 1-hydroxyazulene, and not as its ketonic form.
Guaiazulene was reacted with benzoylperoxide to give 3-benzoyloxyguaiazulene (6) and ben-
zoyloxydiazulenylmethane derivative (7). Reduction of 3-acetoxyguaiazulene (8) obtained from
(6), afforded 3-hydroxyguaiazulene (9) as an unstable green oil in good yield.
Electronic spectrum and NMR of the compound (9) indicate that the compound exists in
hydroxyazulene form. The etheral solution of 9 was allowed to stand at room temperature for
12 hr; the green color gradually changed to brown, from which pale yellow needles (10) and
keto form (11) of 9 were isolated in 59% and 20% yields, respectively. Spectroscopic data
(IR, NMR) of the compound (10) were almost superimposable with those of the product of Darkin
reaction of 3-formylguaiazulene (ref. 4) [we followed the same reaction and obtained a mix-
ture of the reported product and 11 in 10% and 14% yields, respectively.], and also with
dimeric compound (10_2) obtained by oxidation of guaiazulene by Matsubara et al. (ref. 5).
From the detailed analyses of ^{1}H-NMR (Fig. 3) of our product, we propose here that the com-
pound is a diastereomeric mixture of A (meso) and B (enantiomeric mixture) (Scheme 1) in the
ratio of 1:0.8. Methylation of 3-hydoxyguaiazulene (9) with methyl iodide in alkaline condi-
tion afforded 3-methoxyguaiazulene (12) and C-methylation product (13) in 39% and 45% yields,
and a similar reaction of keto form 11 also yielded the same compounds in 37% and 38% yields,
respectively. However, isomerization of 11 to 9 was not observed.
Thus, 1-hydroxyazulene (3) was newly obtained as a green colored substance which easily
decomposed to polymeric substance, and 3-hydroxyguaiazulene (9) was also obtained as an ex-
tremely unstable compound but it gave a mixture of dimeric compound (10) presumably formed by
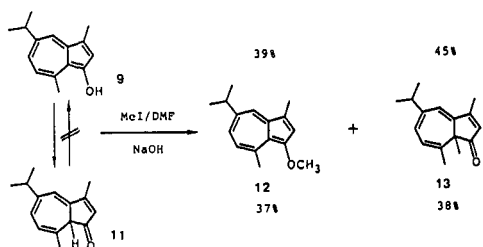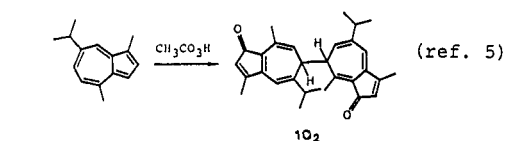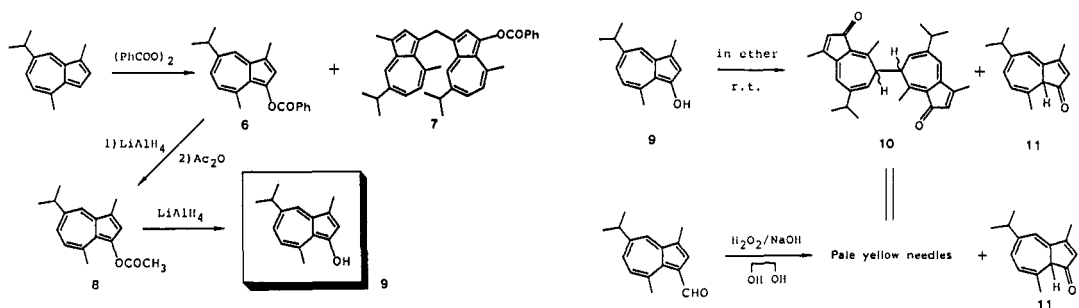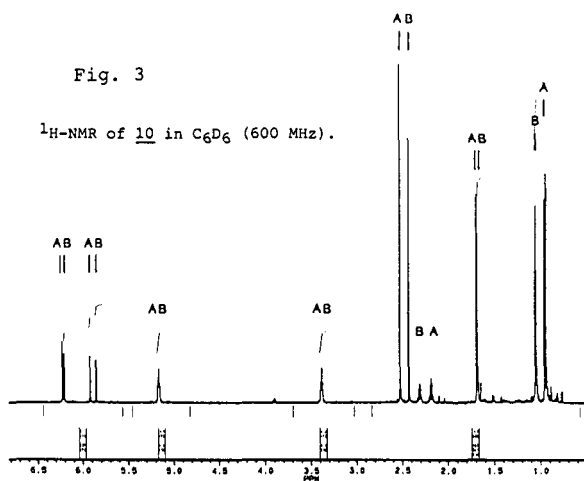oxidative coupling of 9 and isomeric keto form (11).

Fig. 3

^{1}H-NMR of 10 in C_6D_6 (600 MHz).

Scheme 1

A (meso)   B (enantiomeric mixture)
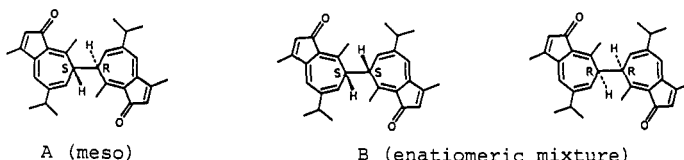
Several reports of the attachment of the sulfur atom to the azulene nucleus have been found
in literature on azulene (ref. 1, 6). However, no report on the synthesis of azulenethiols
has been published, although some efforts have been made in this respect (ref. 6). Here, we
synthesized 1-, 2-, and 6-azulenethiols, isomers of naphthalenethiol.
According to the paper of Replogle (ref. 7), azulene was reacted with sulfur dichloride
yielding di-1-azulenyl sulfide (14) (ref. 7), di-1-azulenyl disulfide (15) (ref. 6), and tri-
azulene derivative (16), in 28%, 17%, and 7.3% yields, respectively. Reductive cleavage of

15 with LiAlH$_4$ afforded 1-azulenethiol (17) as an unstable blue oil in 90% yield.
Reaction of diethyl 2-hydroxyazulene-1,3-dicarboxylate with dimethyllthiocarbamyl chloride in
the presence of sodium hydroxide afforded a mixture of O-dimethylthiocarbamate (18) and S-
dimethylthiocarbamate (19), in 23% and 48% yields, respectively (ref. 6). Heating of 18 af-
forded 19 in quantitative yield. Treatment of 19 with 100% phosphoric acid yielded decar-
boxylation product (20), whose hydrolysis with aqueous potassium hydroxide afforded 2-
azulenethiol (21) as reddish violet prisms, mp 119-121°C. Similarly, the reaction of diethyl
6-hydroxyazulene-1,3-dicarboxylate with dimethylthiocarbamyl chloride afforded O- and S-
dimethylthiocarbamates (22 and 23) in 46% and 17% yields, respectively. Treatment of 23 with
100% phosphoric acid, followed with alkaline hydrolysis, afforded 6-azulenethiol (25), as
blue needles, mp 112-114°C, in 43% yield from 23.
Methylation of newly obtained azulenethiols with diazomethane afforded the corresponding
methylthio derivatives, and oxidation with iodine or DMSO yielded their corresponding disul-
fides. Electronic spectra of azulenethiols (17, 21, 25) show a similar pattern with the cor-
responding methylthioazulenes. These spectra as well as their NMR spectra indicate that these
azulenethiols exist as thiol forms , not as thioketone forms.
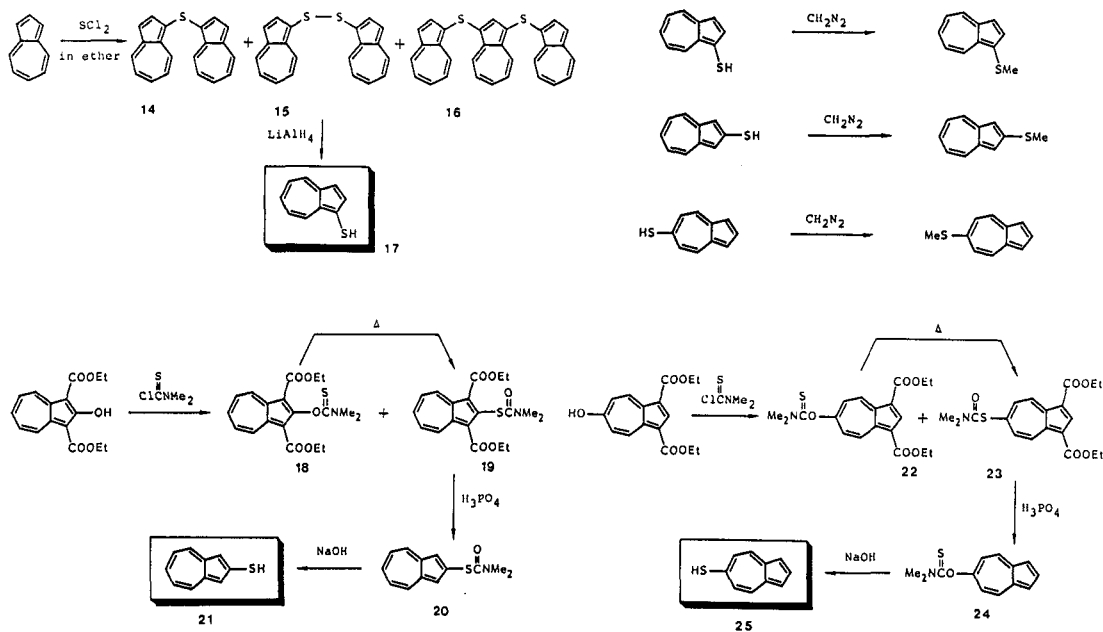
2   Syntheses of diazulenylketone, diazulenylthioketone, diazulenopyridine and
hydroxyazulenylmethylidyneazulanone

Reaction of azulene with oxalyl chloride in methylene chloride afforded a mixture of known
di(1-azulenyl)ketone (26) (ref. 8) and unknown di(1-azulenyl)ethane dione (27) in 34% and 20%
yields, respectively. The ketone was reacted with phosphorous pentasulfide to give a stable
thioketone (28). Reactions of 28 with monoperphthalic acid and with methyl iodide afforded a
stable S-oxide (29) and methylthio cation (30), respectively. The extreme stability of the
thioketone (28) and the S-oxide (29) must be attributable to the strong electron-releasing
property from the seven membered ring to 1 and 3-positions of azulene nucleus.
It has been known that azulenes easily reacted with formaldehyde to give diazulenylmethane
derivatives (ref. 9). The reaction was applied to substituted azulene, and various sub-
stituted diazulenylmethane derivatives were obtained in good yield as shown in Table 1.
However, we found the reaction of ethyl 2-aminoazulene-1-carboxylate (31) with formaldehyde
to afford a mixture of diazulenylmethane (32) and stable azulaneimine (33) having spiro
structure. The latter was easily isomerized to diazulenylmethane derivative (34) with an
eight-membered ring. Furthermore, 2-aminoazulene itself reacted with formaldehyde to give
unexpectedly diazulenopyridine (35) in one pot in 47% yield. Phenyl derivative (36) was also
obtained by a similar reaction with benzaldehyde. The compound (35) has already been syn-
thesized by Morita et al. by a multi-step reaction starting from 2-aminoazulene (ref. 10).
Electronic spectra of the compounds (35 and 36) are shown in Fig. 4.
Reaction of 2-hydroxyazulene (37) with 2-hydroxy-1-formylazulene (38) in the presence of
strong acid afforded bis[1-(2-hydroxyazulenyl)]methyl carbocation (39). When the cation was
treated with water, a neutral compound (40) was obtained as stable crystals in good yield.
Ethoxycarbonyl derivative (R = COOEt) was also obtained in a similar manner. NMR of the com-
pounds showed a symmetrical pattern which indicates that the compound must exist as a fully
conjugated structure (41) having hydrogen bonding consisting of an eight-membered ring.
Electronic spectra of 40 showed a flattened absorption with strong intensity (Fig. 5), dif-
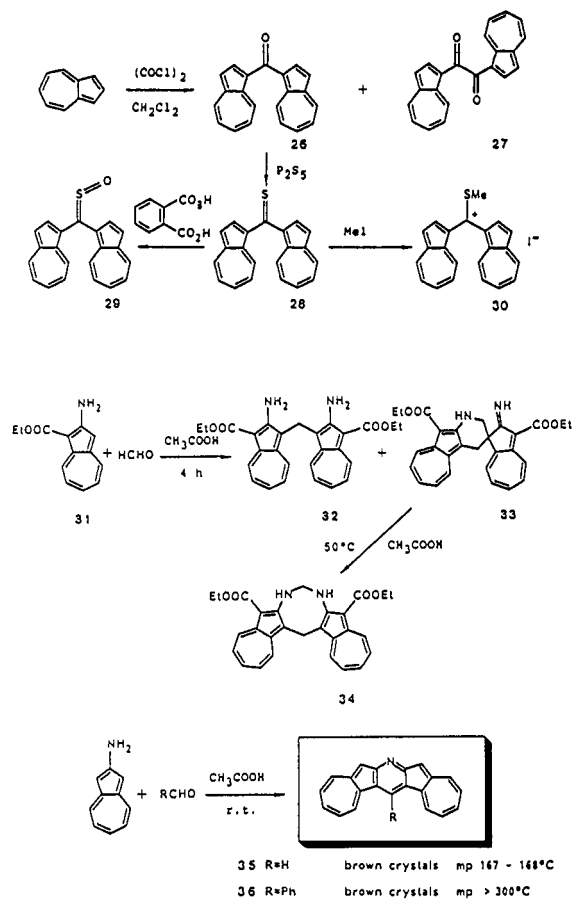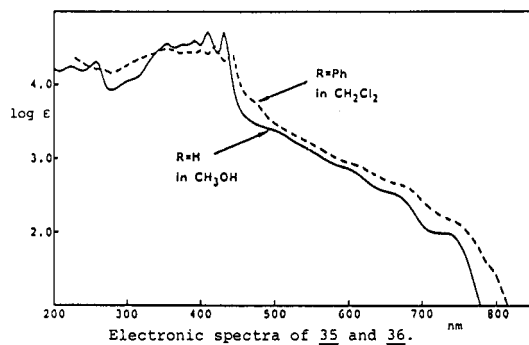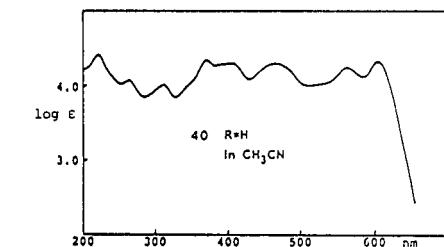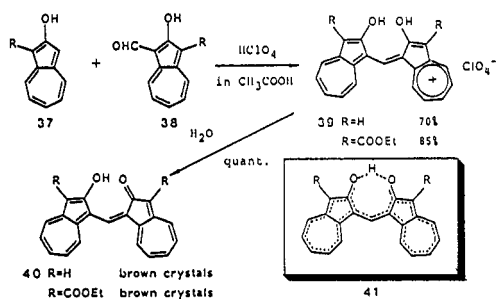ferent from an azulenic absorption pattern.

Table 1. Synthesis of Diazulenylmethane Derivatives

R^1	R^2		mp(°C)	yield(%)
COOEt	OH	orange needles	209 - 211	83
COOEt	NH_2	orange plates	206 - 208	73
H	OMe	red needles	215 - 216	92 - 100
COOEt	OMe	red needles	151 - 152	90
H	NHAc	blue prisms	261 - 263	73
COOEt	NHAc	red prisms	251 - 253	80

Fig. 4

Electronic spectra of 35 and 36.

Fig. 5 Electronic spectra of 40 in CH_3CN.

3 Synthesis of tri(1-azulenyl)methyl carbocations

Recently various extremely stable hydrocarbon carbocations, shown in Scheme 2 as examples, have appeared in the literature (ref. 11). Many stable cations including azulene nucleus, e.g., di(1-azulenyl)methyl and tri(1-azulenyl)methyl carbocations have also been reported. However, no report on the pK_R+ value of tri(1-azulenyl)methyl carbocation has been made.
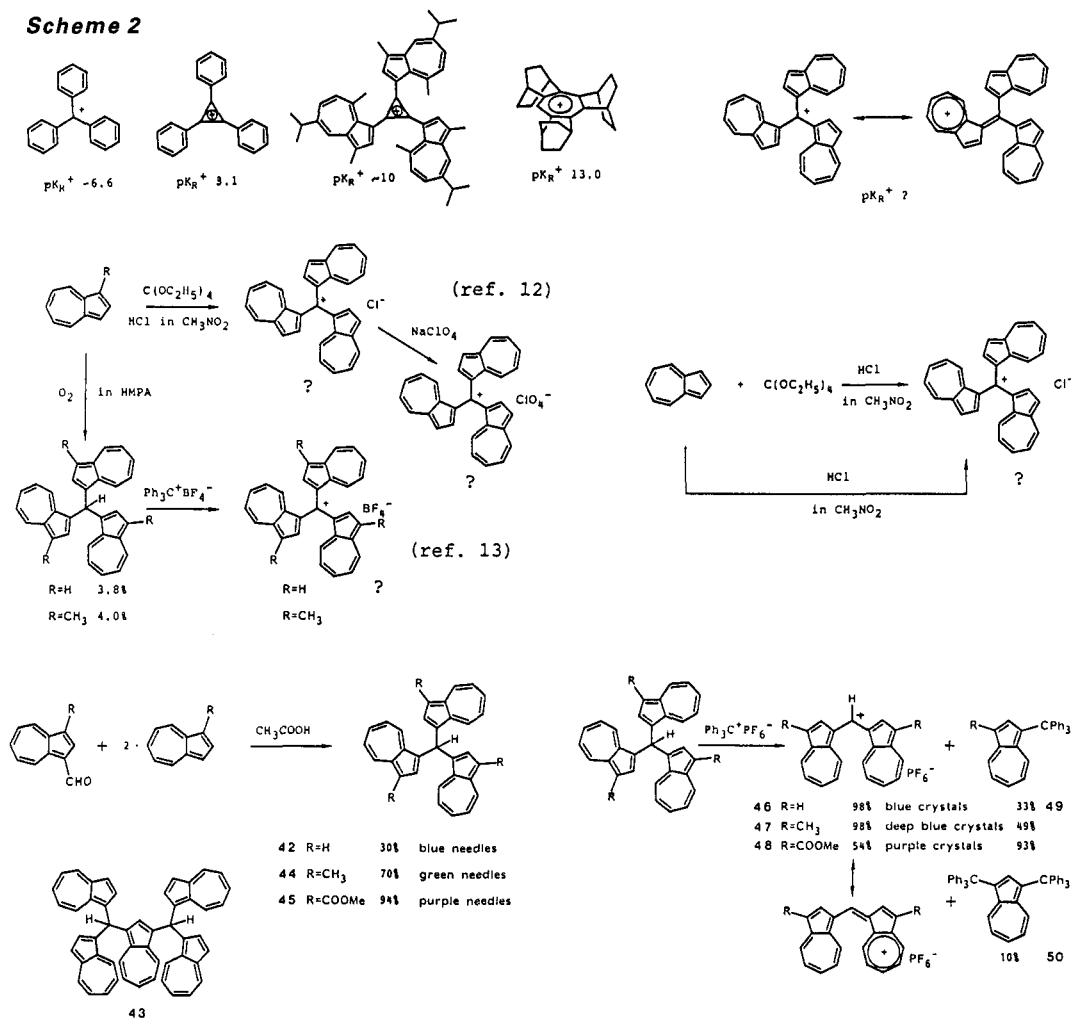
Synthesis of tri(1-azulenyl)methyl carbocation has been reported by two methods; one by the reaction of azulene with tetraethyl orthocarbonate $[C(OEt)_4]$ in the presence of acid reported by Hafner et al. (ref. 12), and the other by the hydride abstraction from tri(1-azulenyl)methane by triphenylmethyl carbocation reported by Matsubara et al. (ref. 8, 13).

We also obtained the same compound with the former cation but we found the NMR spectra of this compound was too complex to analyse. Furthermore, we isolated some cation by the reaction of azulene in nitromethane-hydrogen chloride without tetraethyl orthocarbonate. IR of this compound was superimposable with the Hafner's cation. Therefore, the structure of this cation is doubtful.

The reaction of 1-formylazulene with two moles of azulene in acetic acid at room temperature afforded tri(1-azulenyl)methane (42) in 30% yield together with pentaazulene derivative (43) in 14% yield. Similar reaction of 3-methyl- and 3-methoxycarbonyl-1-formylazulenes with the substituted azulenes also yielded the corresponding tri(1-azulenyl)methanes (44 and 45) in

70% and 94% yields, respectively. Reaction of these tri(1-azulenyl)methanes with triphenyl-methyl carbocation unexpectedly yielded the corresponding di(1-azulenyl)methyl carbocation (46, 47, and 48) by extrusion of one azulene ring, together with 1-triphenylmethylazulene derivatives (49) in good yield, and 1,3-bis(triphenylmethyl)azulene (50) from 42. Therefore, tri(1-azulenyl)methyl carbocations obtained by Matsubara et al. are also doubtful.

Scheme 2

Finally we obtained the objective tri(1-azulenyl)methyl carbocations by the following method. The triazulenylmethanes were treated with dilchlorodicyano-p-benzoquinone (DDQ) in methylene chloride, followed by addition of hexafluorophosphoric acid; working up by extraction with methylene chloride yielded the corresponding tri(1-azulenyl)methyl carbocation (51, 52 and 53) in good yield as deep colored crystals. High resolution mass spectra of these cations by HAB method show the correct parent ion peaks. Electronic absorption spectra of these cations are shown in Fig. 6. Cyclic voltamgram of 51 is also shown in Fig. 7. pK_R^+ Values of these cations (51, 52 and 53) determined spectrophotometrically in buffer prepared in 50% aqueous acetonitrile were very high values of 11.3, 11.4 and 10.4, respectively. As expected, methyl substituent increases the stability of the cation and methoxycarbonyl decreases the stability. These values are about 3-4 pK_R^+ unit higher than those of the corresponding di(1-azulenyl)methyl carbocations measured by us using the same method.

^{1}H-NMR spectra of these cations in deuteriochloroform at room temperature showed broad signals; however, at higher temperature, clear and sharp spectra analyzable by first order were obtained. The NMR spectra of methyl substituted derivative (52) measured at various temperature between -60°C - +58°C was shown in Fig. 8. Similar spectral patterns were also obtained for the other two cations. The spectra must be explained by the assumption that these cations are not coplaner, and they exist in equilibrium between two conformers as shown in Scheme 3 caused by restricted rotation at low temperature; thus, one is an asymmetrical propeller type conformer and the other is a symmetrical propeller type in the ratio of about 3 : 1.

Acknowledgement

51	R=H	56% brown powder
52	R=CH₃	100% brownish purple powder
53	R=COOMe	100% purple powder

pK$_R^+$

R=H	11.3
R=CH₃	11.4
R=COOMe	10.4

R=H	7.3
R=CH₃	8.4
R=COOMe	2.1

Fig. 6

Electronic spectra of tri(1-azulenyl)methyl carbocations in CH₃CN.

Fig. 7

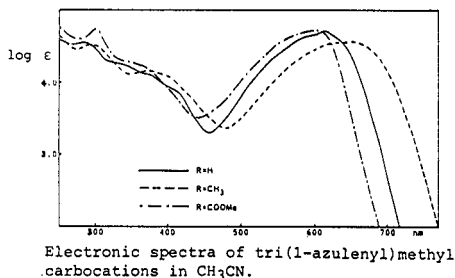Cyclic voltammetry of tri(1-azulenyl)methyl carbocation in 0.1M Et₄NClO₄/CH₃CN.

Variable temperature ¹H-NMR of 52 in CDCl₃.

Fig. 8

Scheme 3

Asymmetrical Propeller
CH₃, H: non-equivalent

Symmetrical Propeller
CH₃, H: equivalnet
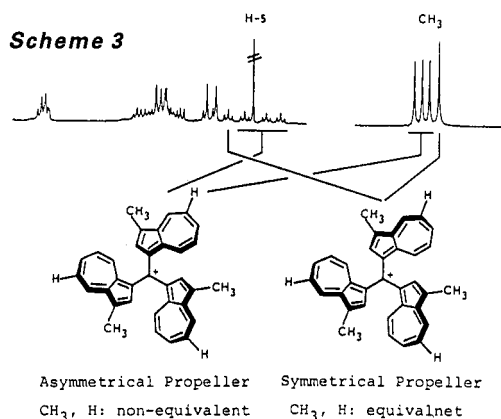
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