Azulenic novel $\pi$-electronic compounds

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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, thiketone and their derivatives, and novel $\pi$-electronic compounds such as diazulenopyridine and hydroxyazululylpyrideneazulanone were synthesized. 3) tri-(1-azulenyl)methylcarbocation and its 3-methyl and 3-methoxycarbonyl derivatives were synthesized. They showed high pK$_a$+ 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 $\pi$-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 substance (ref. 3). Chiurdoglu and Fuka (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 LiAlH$_4$, afforded an inseparable mixture of unstable green oil and benzylalcohol. Acetylation of the products yielded 1-acetoxyazulene (g), whose reduction with LiAlH$_4$ afforded pure 1-hydroxyazulene (2), after working up under low temperature, as green oil in quantitative yield. The compound (2) is considerably stable at -30°C, but easily polymerized at room temperature and no ketonic compound was obtained. 1-Hydroxy-2-deuteroazulene (fl) was also obtained starting from 2-deuteroazulene. Visible absorption spectra (Fig. 1) of (2, 2) and 3-methoxyazulene (d), which showed a similar pattern, as well as $^1$H-NMR spectra including variable temperature spectra (Fig. 2) indicate that the

![Chemical structures and spectra](https://example.com/structure.png)

Fig. 1

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

Fig. 2

$^1$H-NMR of 2 in Acetone-$d_6$ (90 MHz).
compound (3) exists as 1-hydroxyazulene, and not as its ketonic form. Guaiazulene was reacted with benzoylperoxide to give 3-benzoyloxyguaiazulene (5) and benzoyloxydiazulenylmethane derivative (6). 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 ethereal 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 mixture of the reported product and 11 in 10% and 14% yields, respectively), and also with dimeric compound (10Q) obtained by oxidation of guaiazulene by Matsubara et al. (ref. 5). From the detailed analyses of 1H-NMR (Fig. 3) of our product, we propose here that the compound is a diastereomeric mixture of A (meso) and B (enantiomeric mixture) (Scheme 1) in the ratio of 1:0.8. Methylation of 3-hydroxyguaiazulene (9) with methyl iodide in alkaline condition 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 extremely unstable compound but it gave a mixture of dimeric compound (10) presumably formed by oxidative coupling of 9 and isomeric keto form (11).

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 naphthenethiol. 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

![Scheme 1](attachment://Scheme_1.png)

Fig. 3

1H-NMR of 10 in CD6 (600 MHz).

![A (meso)](attachment://A.png)

![B (enantiomeric mixture)](attachment://B.png)
Reactions and syntheses of azulenic novel n-electronic compounds

15 with LiAlH₄ afforded 1-azulenethiol (17) as an unstable blue oil in 90% yield. Reaction of diethyl 2-hydroxyazulene-1,3-dicarboxylate with dimethylthiocarbamyl 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 afforded 19 in quantitative yield. Treatment of 19 with 100% phosphoric acid yielded decarbonylation product (20), whose hydrolysis with aqueous potassium hydroxide 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 disulfides. Electronic spectra of azulenethiols (E, 21, i) show a similar pattern with the corresponding 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-azulene)ketone (26) (ref. 8) and unknown di(1-azulene)ethane dione (a) in 34% and 20% yields, respectively. The ketone was reacted with phosphorous pentasulfide to give a stable thioketone (27). Reactions of 27 with monoperphthalic acid and with methyl iodide afforded a stable S-oxide (29) and methylthio cation (x), respectively. The extreme stability of the thioketone (29) 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 substituted diazulenylmethane derivatives were obtained in good yield as shown in Table 1. However, we found the reaction of ethyl 2-aminoazulene-1-carboxylate (11) with formaldehyde to afford a mixture of diazulenylmethane (32) and stable azulaneimine (s) 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 (21) in one pot in 47% yield. Phenyl derivative (36) was also obtained by a similar reaction with benzaldehyde. The compound (35) has already been synthesized 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. Ethoxy carbonyl derivative (R = COOEt) was also obtained in a similar manner. NMR of the compound 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), different from an azulenic absorption pattern.
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 \( pK_{a} \) 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 \([\text{C(OEt)}_4]\) 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 analyze. 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-azuleny1)methanes with triphenylmethyl carbocation unexpectedly yielded the corresponding di(1-azuleny1)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-azuleny1)methyl carbocations obtained by Matsubara et al. are also doubtful.

Finally we obtained the objective tri(1-azuleny1)methyl carbocations by the following method. The triazulenylmethanes were treated with dichlorodicyano-p-benzoquinone (DDQ) in methylene chloride, followed by addition of hexafluorophosphoric acid; working up by extraction with methylene chloride yielded the corresponding tri(1-azuleny1)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 voltanagram of 51 is also shown in Fig. 7. $pK_{a}^{+}$ 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 $pK_{a}^{+}$ unit higher than those of the corresponding di(1-azuleny1)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 coplanar, 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.

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Cyclic voltammetry of tril(1-azulenyl)methyl carbocations in CH$_2$CN.

**Scheme 3**

- Asymmetrical Propeller
- Symmetrical Propeller

**REFERENCES**