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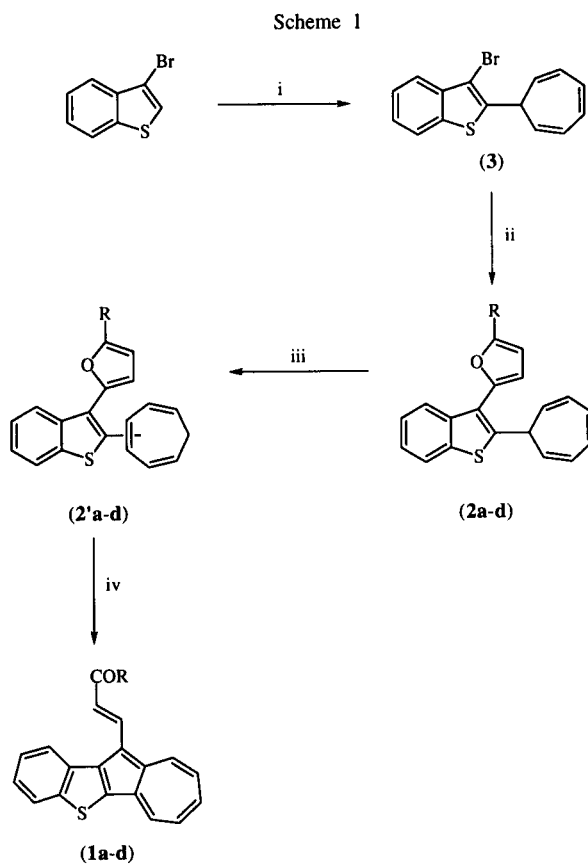
2-Cycloheptatrienyl-3-(2-furyl)benzothiophenes, which are prepared by Stille coupling reaction of 2-cycloheptatrienyl-3-bromobenzothiophene with the 5-substituted 2-trimethylstannylfurans, react with triphenylmethyl tetrafluoroborate to give the corresponding azuleno[1,2-*b*]benzothiophenic enones in excellent yields.

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Heteroaromatic fused ring systems containing azulene nuclei are of interest not only for their fundamental viewpoints, but also their applied ones, especially, physiological activity. So several kinds of such compounds have been prepared [1]. Synthetic methods were restricted to the heteroaromatization of the azulene or the Takase and Yasunami's reaction between 2*H*-cyclohepta[*b*]furan-2-one and enamines. Synthetic difficulties have impeded progress in this area. Recently we reported a novel, one-pot synthesis of tricyclic benz[*a*]azulenes having an α,β -unsaturated ketone group from the corresponding *o*-cycloheptatrienyl benzenes [2]. This reaction seems to involve a ring-unravelling reaction of the furan ring by intramolecular electrophilic attack of the tropylium ion onto the 2-position of the furan ring. Although the ring-opening reaction of 2-substituted furans with protic acid to afford the corresponding 1,4-diketones is well-known [3], the above ring-opening reaction with the tropylium ion to give an azulene unit is the only example reported to date. Hence, we wanted to apply such type of reaction to see the scope and limitations of the reaction and to construct novel heteroaromatic fused azulene rings.

In this communication we wish to report a new, facile, one-pot synthesis of azuleno[1,2-*b*]benzothiophenic enones (**1**), which include the novel tetracyclic π -conjugated azulene nucleus cata-condensed with benzothiophene ring, from the corresponding 2-cycloheptatrienyl-3-(2-furyl)benzothiophenes (**2**).

The synthetic sequence leading to **1** from the readily available 3-bromobenzothiophene is depicted in Scheme 1. 3-Bromobenzothiophene [4] was treated with LDA in THF at -78 °C, followed by addition of an equimolar of tropylium tetrafluoroborate to give 2-cycloheptatrienyl-3-bromobenzothiophene (**3**) [5] 65% yield. The palladium(II)-catalyzed Stille coupling reaction [6] of **3** with 5-substituted 2-trimethylstannylfurans (**4**) [5,7] gave the



Reagents and Conditions:

i) LDA in THF, $C_7H_7^+BF_4^-$

ii) R - $SnMe_3$, $PdCl_2(PPh_3)_2$
(4a-d)

iii) Xylene, reflux

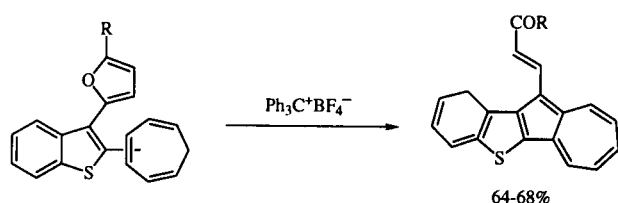
iv) $Ph_3C^+BF_4^-$, Dichloromethane, reflux

corresponding 2-cycloheptatrienyl-3-(2-furyl)benzothiophenes (**2**) [5] in 72-78% yields as pale yellow oil. In order to decrease the steric hindrance at the subsequent hydride-abstraction process, **2** was then thermally isomerized by sigmatropic rearrangement to an isomeric mixture of **2** and **2'** [5]. The isomeric mixture **2** and **2'** was treated with an equimolar amount of triphenylmethyl tetrafluoroborate in dichloromethane at 0 °C and subsequent refluxing the reaction mixture for 1 hour gave the corresponding azuleno[1,2-*b*]benzothiophenic enones (**1**) in 64-68% yields (Table 1). The structures of these azulene derivatives were established by their nmr, ir, uv-vis and ms spectra as well as elemental analyses [8]. When 2-cycloheptatrienyl-3-[2-(5-methyl)furyl]benzothiophene (**2a** + **2'a**) was treated with an equimolar amount of triphenylmethyl tetrafluoroborate at 0 °C for 5 minutes, followed by addition of dry ether, 2-tropylio-3-[2-(5-methyl)furyl]benzothiophene (**5a**) was obtained as a reddish-violet powder in 85% yield. Refluxing the dichloromethane solution of **5a** also gave **1a** in 66% yield.

Table 1
Novel Synthesis of Azuleno[1,2-*b*]benzo[*b*]thiophenes

| Cycloheptatrienes | R | Azulenes | Yield [a] |
|-------------------|--|-----------|-----------|
| 2a | CH ₃ | 1a | 64% |
| 2b | CH ₃ CH ₂ | 1b | 66% |
| 2c | CH ₃ (CH ₂) ₃ CH ₂ | 1c | 65% |
| 2d | CH ₃ (CH ₂) ₁₆ CH ₂ | 1d | 68% |

[a] Isolated yield.



R = CH₃, CH₃CH₂, CH₃(CH₂)₃CH₂, CH₃(CH₂)₁₆CH₂

Since the starting materials, 2-substituted furans and 3-bromobenzothiophene are readily available, the procedure is simple and easy, the yields are moderate to good, and, further, the formation of the azuleno[1,2-*b*]benzothiophene ring is difficult by other synthetic methods, it is considered that this is a valuable synthetic methodology leading to a diversity of azuleno[1,2-*b*]benzothiophenic enones.

EXPERIMENTAL

All melting points were uncorrected. The ¹H nmr spectra were obtained on a Bruker DPX-250 spectrometer (250 MHz) using tetramethylsilane as an internal reference. The mass spectra were determined with Shimadzu GC-MS QP200A spectrometer.

Preparation of 2-Cycloheptatrienyl-3-bromobenzothiophene (**3**).

To a solution of 2-bromobenzothiophene (33 mmoles) in 300 ml of dry tetrahydrofuran, 19.8 ml of lithium diisopropylamide (2.0 M solution in heptane/tetrahydrofuran/ethylbenzene, 39 mmoles) was added dropwise under nitrogen at -78 °C. The mixture was stirred for 2 hours at -78 °C. Then powdered tropylium tetrafluoroborate was added dropwise. The mixture was stirred for 12 hours at room temperature. The usual workup gave **3** in 65% yield as colorless crystals, mp 62-63 °C. ¹H nmr (CDCl₃): δ 3.43 (1H, t, J = 5.5 Hz, seven-membered ring), 5.47-5.52 (2H, dd, J = 9.1, 5.6 Hz, seven-membered ring), 6.28-6.32 (2H, br, seven-membered ring), 6.75-6.78 (2H, dd, J = 3.0, 3.0 Hz, seven-membered ring), 7.33-7.48 (2H, m, benzothiophene), 7.76-7.84 (2H, m, benzothiophene), ms: m/z 304 (M⁺), 302, 301, 223, 178, 111.

Anal. Calcd. for C₁₅H₁₁SBr: C, 59.42; H, 3.66. Found: C, 59.22; H, 3.47.

General Procedure for the Synthesis of 2-Cycloheptatrienyl-3-(2-furyl)benzothiophenes (**2**).

The mixture of **3** (4.5 g, 14.9 mmoles), 2-alkyl-5-trimethylstannylfuran (**4**) (21 mmoles), bis(triphenylphosphine)palladium(II) chloride (5 g, 7.1 mmoles) and 200 ml of tetrahydrofuran was refluxed for 8 hours. The usual workup gave the corresponding 2-cycloheptatrienyl-3-(2-furyl)benzothiophenes (**2**).

Thermal Isomerization of **2** to **2'**.

The xylene solution of **2** was refluxed for 5 hours. The solvent was evaporated *in vacuo* and then the residue was chromatographed over silica gel to give **2'** in almost quantitative yield.

General Procedure for the Synthesis of Azuleno[1,2-*b*]benzothiophenic Enones (**1**).

A solution of **2'** (52.6 mmoles) in 5 ml of dry dichloromethane was added to a solution of triphenylmethyl tetrafluoroborate (180 mg, 54.5 mmoles) in dry dichloromethane (10 ml) at 0 °C and was stirred for 10 minutes. Then, dry dichloromethane (80 ml) was added and the mixture was refluxed for 1 hour. The solvent was removed under reduced pressure and purified by column chromatography (silica-gel, hexane-ethyl acetate) and recrystallization from toluene to afford **1**. The physical properties of **1** are given below.

E-5-(11-Azuleno[1,2-*b*]benzo[*b*]thiophenyl)-3-buten-2-one (**1**).

This compound was prepared by the general method given above: mp 166-169 °C; ¹H nmr (CDCl₃): δ 2.49 (3H, s, CH₃), 6.91 (1H, d, J = 16.0 Hz, olefin), 7.18-7.29 (2H, m, seven-membered ring), 7.46-7.53 (2H, m, benzothiophene), 7.60 (1H, dd, J = 10.2 Hz, 9.8 Hz, seven-membered ring), 7.87-7.94 (1H, m, benzothiophene), 8.27 (1H, d, J = 9.2 Hz, seven-membered ring), 8.39-8.45 (1H, m, benzothiophene), 8.43 (1H, d, J = 16.0 Hz, olefin), 8.63 (1H, d, J = 9.8 Hz, seven-membered ring); ir (KBr): ν_{C=O} = 1643 cm⁻¹; ms: m/z 302 (M⁺), 302, 301, 258, 129, 111.

Anal. Calcd. for C₂₀H₁₄OS: C, 79.44; H, 4.67. Found: C, 79.29; H, 4.77.

E-6-(Azulino[1,2-*b*]benzo[*b*]thiophenyl)-4-penten-3-one (**1b**).

This compound was prepared by the general method given above: mp 138-141 °C, ¹H nmr (CDCl₃): δ 1.28 (3H, t, J = 7.3 Hz, CH₃), 2.82 (2H, q, J = 7.3 Hz, CH₂), 7.00 (1H, d, J = 16.0 Hz, olefin), 7.22-7.38 (2H, m, seven-membered ring), 7.49-7.59 (2H, m, benzothiophene), 7.66 (1H, dd, J = 10.0, 9.7 Hz, seven-membered ring), 7.92-8.02 (1H, m, benzothiophene), 8.37 (1H, d, J = 9.2 Hz, seven-membered ring), 8.43-8.50 (1H, m, benzothiophene), 8.56 (1H, d, J = 16.0 Hz, olefin), 8.67 (1H, d, J = 10.0 Hz, seven-membered ring); ir (KBr): ν_{C=O} = 1655 cm⁻¹; ms: m/z 316 (M⁺), 287, 258, 171, 149, 129, 111.

Anal. Calcd. for C₂₁H₁₆OS: C, 79.71; H, 5.10. Found: C, 79.58; H, 5.22.

E-1-(1)-Azuleno[1,2-*b*]benzo[*b*]thiophenyl)-1-octen-3-one (**1c**).

This compound was prepared by the general method given above: mp 67-70 °C, ¹H nmr (CDCl₃): δ 0.98 (3H, t, J = 6.4 Hz, CH₃), 1.44 (4H, m, 2 x CH₂), 1.81 (2H, m, CH₂), 2.86 (2H, m, CH₂), 6.95 (1H, d, J = 15.9 Hz, olefin), 7.18-7.30 (2H, m, seven-membered ring), 7.46-7.53 (2H, m, benzothiophene), 7.62 (1H, dd, J = 9.9 Hz, 9.8 Hz, seven-membered ring), 7.90-7.96 (1H, m, benzothiophene), 8.36 (1H, d, J = 9.2 Hz, seven-membered ring), 8.41-8.46 (1H, m, benzothiophene), 8.51 (1H, d, J = 15.9 Hz, olefin), 8.60 (1H, d, J = 10.2 Hz, seven-membered ring); ir (KBr): ν_{C=O} = 1654 cm⁻¹; ms: m/z 358 (M⁺), 287, 258, 247, 129.

Anal. Calcd. for C₂₄H₂₂OS: C, 80.41; H, 6.19. Found: C, 80.21; H, 6.38.

E-1-(1)-Azuleno[1,2-*b*]benzo[*b*]thiophenyl)-1-henicosen-3-one (**1d**).

This compound was prepared by the general method given above: mp 82-84 °C, ¹H nmr (CDCl₃): δ 0.88 (3H, t, J = 6.4 Hz, CH₃), 1.26 (30H, m, 5 x CH₂), 1.80 (2H, m, CH₂), 2.78 (2H, t, J = 7.5 Hz, CH₂), 6.99 (1H, d, J = 16.0 Hz, olefin), 7.25-7.38 (2H, m, seven-membered ring), 7.48-7.56 (2H, m, benzothiophene),

7.63 (1H, dd, J = 9.8, 9.3 Hz, seven-membered ring), 7.89-7.98 (1H, m, benzothiophene), 8.35 (1H, d, J = 9.3 Hz, seven-membered ring), 8.43-8.50 (1H, m, benzothiophene), 8.56 (1H, d, J = 16.0 Hz, olefin), 8.67 (1H, d, J = 10.0 Hz, seven-membered ring); ir (KBr): ν_{C=O} = 1660 cm⁻¹; ms: m/z 540 (M⁺), 287, 258, 247, 171, 111.

Anal. Calcd. for C₃₇H₄₈OS: C, 82.17; H, 8.95. Found: C, 82.30; H, 8.87.

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