From Phenols to Azulenes: An Extended and Versatile Route to Polyalkylated Azulenes with Variable Substitution Patterns at the Seven- and Five-membered Ring

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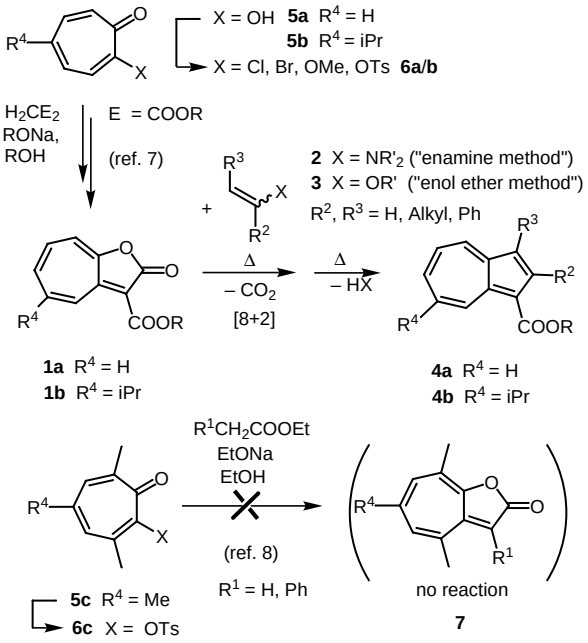
Abstract: Polyalkylated azulenes can easily be prepared from polyalkylphenyl propiolates which are transformed by dynamic gas phase thermo-isomerization (DGPTI) into polyalkylcyclohepta[*b*]furan-2(2*H*)-ones. The latter react thermally with enol ethers or enamines to the corresponding azulenes. The enamines may be generated in situ from corresponding aminals, especially, in cases where it is difficult to obtain the pure enamines due to their high reactivity.

Key words: azulene syntheses, polyalkylated azulenes, cyclohepta[*b*]furan-2(2*H*)-ones, enamine formation in situ

For our work on molecular switches[1] and protocolchicinoids[2] on heptalene basis we needed for the synthesis of the starting heptalenedicarboxylates[1f,3] highly alkylated and functionalized azulenes.[4] Despite a huge number of azulene syntheses that have been reported over the past 60 years,[5] there are no practical short syntheses of polyalkylated azulenes known so far,[3,5,6] (see also ref.[4] for a detailed discussion of this point).

An interesting and variable synthesis of azulenes, based on the cycloaddition of cyclohepta[*b*]furan-2(2*H*)-ones **1** and enamines **2** or enol ethers **3**, has been developed by Nozoe and Takase et al.[7] The principle is shown in Scheme 1. Mainly, five-ring-substituted azulenes **4** are conveniently prepared by this procedure, since it depends on the accessibility of the cyclohepta[*b*]furan-2(2*H*)-ones **1**, which can be prepared by base-catalyzed condensation reaction of tropolone derivatives **6** with C–H acidic compounds such as, e.g., alkyl carboxylates.[7h,i] However, a disadvantage of this approach is that the condensation reaction does not work well with alkylated tropolones such as 3,5,7-trimethyltropolone derivative **6c**, as we have found (Scheme 2, Table).[8] In addition, the synthesis of variably substituted tropolones as precursors for the correspondingly substituted azulenes may also become tedious.[9]

Cyclohepta[*b*]furan-2(2*H*)-ones **12** bearing alkyl subtituents at the seven-membered ring can be obtained in one step by flash vacuum pyrolysis (FVP; 650 °C, 10^{-4} Torr)



Scheme 1

of corresponding phenyl propiolates **9**,[10] which, in turn, are easily available from the corresponding phenols **8** (Scheme 2).[4]

Recently, we have reported[4] on the formation of azulene **14** in >50% yield on heating of **12c** in the presence of 3 mol equiv to 5 mol equiv of 1-(cyclohex-1-enyl)pyrrolidine (**13**)[11] in toluene (or *t*-BuOH) at 120 °C in a Schlenk tube for 12–14 h (cf. also ref.[7a] for conditions). The highly alkylated homologous azulenes **33** and **34** were obtained in the same way with enamine **13** from the cyclohepta[*b*]furan-2(2*H*)-ones **12d**, and **12e**, respectively (Scheme 4).[4] These experiments demonstrate that cyclohepta[*b*]furan-2(2*H*)-ones with alkyl substituents at C(4) and C(8) can also be transformed into azulenes according to the described procedures.[7] In general, the addition of the electron-rich enamines **2** or enol ethers **3** to cyclohepta[*b*]furan-2(2*H*)-ones **12** proceeds regioselectively and provides therefore general and facile access to various 1- and 2-substituted polyalkylazulenes in a simple 'one-pot' operation (Scheme 3).[7b,c] As we found now, vetivazulene (**16**)[12] is obtained in 70–80% yield[13] by heating[4] **12b** with

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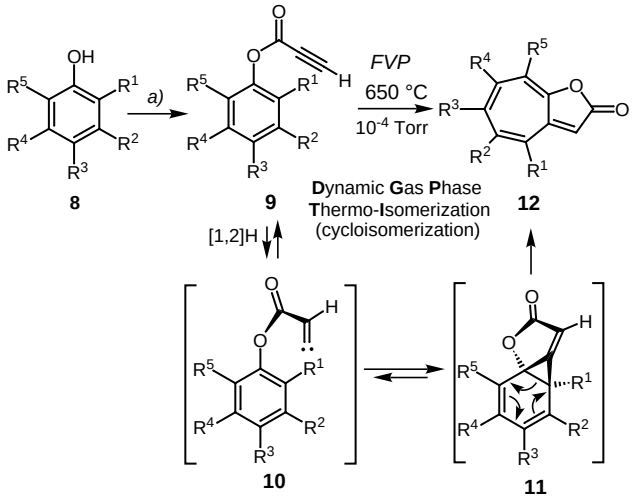
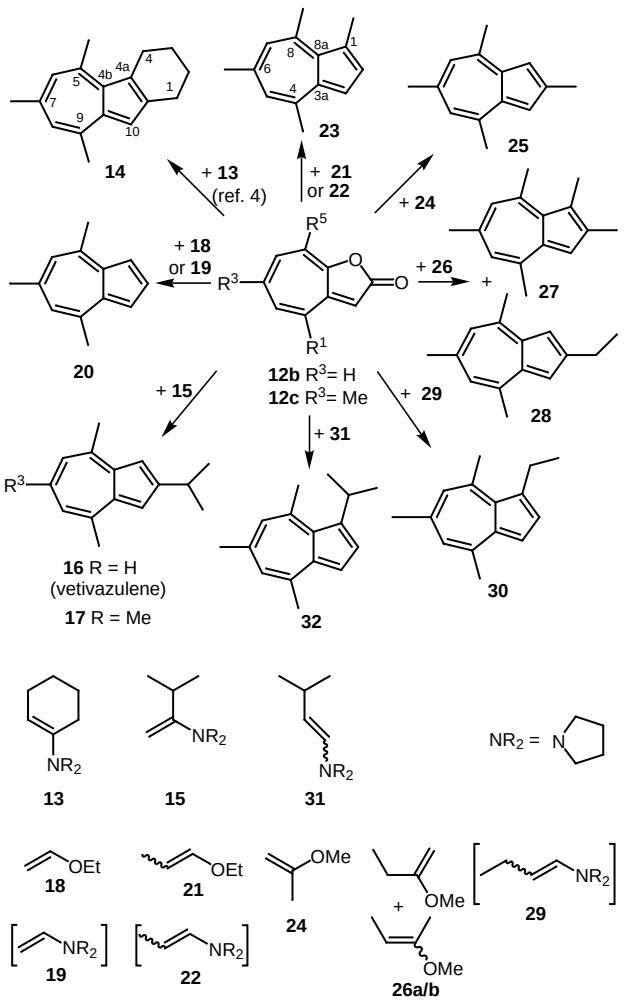


Scheme 2 For details, see ref.[4] and literature therein.

Table Preparation of Cyclohepta(*b*)furan-2(2*H*)-ones **12**

8, **9**, **12**	R^1	R^2	R^3	R^4	R^5	Yield [%] ref.[10]	Yield [%] ref.[3,4]
a	H	H	H	H	H	30–45	35–50
b	Me	H	H	H	Me	45–50	35–50
c	Me	H	Me	H	Me	45–50	30–50
d	Me	Me	H	Me	Me	–	25–45
e	Me	Me	Me	Me	Me	–	15–40



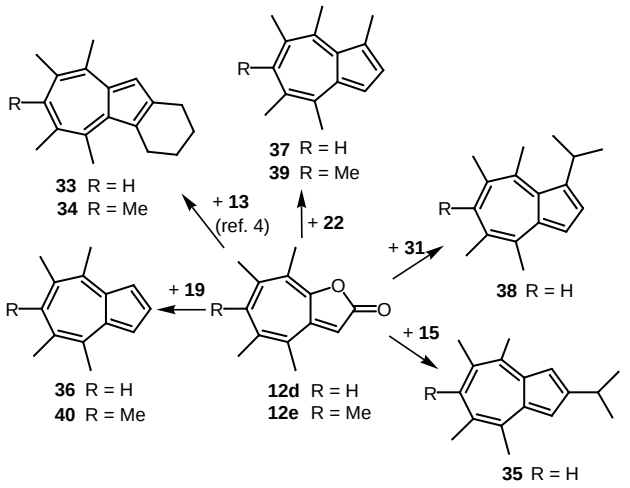
Scheme 3 (For conditions and details, see text).

an excess of enamine[13] **15** for 12–16 h ('enamine method') at 120–30 °C. Reacting enamine **15** with tri- and tetraalkylcyclohepta[*b*]furan-2(2*H*)-one **12c**, and **12d**, respectively, gave the corresponding new tri- and tetramethylated analogs **17**, and **35** (Scheme 4), respectively, in comparable good yields.[15]

In general, higher temperatures and longer reaction times are required for the same reactions of vinyl ethers **3** with cyclohepta[*b*]furan-2(2*H*)-ones **12** ('vinyl ether method').[7] We used as high boiling and polar solvents *N*-methylpyrrolidone (NMP) or triethylene glycol dimethyl ether (TEGDME) both of which can easily be removed from the product mixtures by washing with water during the work-up procedure, thereby avoiding tedious evaporation procedures of low volatile organic solvents. Test runs with solutions of **12c** (typical 0.2–0.5 g) in NMP (5 mL or 20 mL) at 200–220 °C with 3–5 mol equiv of vinyl ethyl ether (**18**) for 60 h in a stainless steel autoclave (10 mL or 40 mL) gave the known 4,6,8-trimethylazulene[15] (**20**) in 58–70% yield.[23] Analogously, heating of **12c** together with an (*E*)/(*Z*)-mixture (~1:3) of 1-ethoxy-1-propene (**21**) in TEGDME for 4 d led to the known 1,4,6,8-tetramethylazulene[17] (**23**) in 38% yield, thus avoiding its two-step synthesis from **20**.[23] The isomeric 2,4,6,8-tetramethylazulene[18] (**25**) was obtained in a similar manner by heating **12c** together with 2-methoxy-propene (**24**) in NMP (220 °C, 5 d, 85–90% yield).[17,23] Heating of **12c** in the presence of a mixture of the 2-butenyl methyl ethers **26a/b** (ratio ca. 1:1) in NMP (10 d, 220 °C) gave a 1:1 mixture of the known 1,2,4,6,8-pentamethylazulene[18] (**27**) and the new 2-ethyl-4,6,8-trimethylazulene (**28**), which were not further separated.[23]

Enamines are more reactive in azulene forming reactions with cyclohepta[*b*]furan-2(2*H*)-ones **1** or **12a**. However, whereas any type of enol ethers are easily available, enamines of simple aldehydes and ketones are difficult to obtain in pure form due to their high reactivity. In 1993, Yasunami et al. described the synthesis of 1-alkylazulenes from methyl 2-oxo-2*H*-cyclohepta[*b*]furan-3-carboxylate (**2a**) with in situ generated enamines with morpholine as amino part.[7f] Our cyclohepta[*b*]furan-2(2*H*)-ones **12**, carrying Me groups at the seven-membered ring, turned out to be too less reactive for the thermal reaction with in situ generated 1-morpholino-alkenes. Nevertheless, enamines with the strongly electron donating pyrrolidino moiety,[19] generated in situ by thermolysis of the corresponding aminals,[20] and **12** gave rise to the formation of the expected azulenes.

Thus, with butanal as starting aldehyde and **12c**, 1-ethyl-4,6,8-trimethylazulene (**30**)[21a,b] was formed in >70% yield (130 °C, 14 h, via in situ generated enamine **29**).[23] In analogy, isovaleraldehyde/pyrrolidine and **12c** (in TEGDME, 140–160 °C, 2 d) gave 1-isopropyl-4,6,8-trimethylazulene (**32**)[21c] in >40% yield.[23] The in situ 'enamine method' could also be applied to **12c** and propanal (*via* **22**, in TEGDME or NMP, 130–140 °C, 12–48 h, 30–70% yield), whereby azulene **23** was obtained at much lower temperatures and in higher average yields than by the enol ether reaction with **21** which took place at 200–220 °C.[17,23] Finally, also 4,6,8-trimethylazulene (**20**) was formed in at least 45–55% yield by reacting **12c** with acetaldehyde/pyrrolidine at 130 °C for 12–24 h.[16,23]



Scheme 4 (For conditions and details, see text).

4,5,7,8-Tetramethyl- and especially 4,5,6,7,8-pentamethylcyclohepta[*b*]furan-2(2*H*)-one (**12d** and **12e**, respectively) are definitely more strained than **12b** or **12c**.[1f] Nevertheless, **12d** reacted not only with pure enamine **13** as we have already reported,[4] but also with the in situ generated enamines **19**, **22**, and **31** leading to the formation of the corresponding new polymethylated azulenes **36**, **37**, and **38**, respectively, in yields of 30–60%.[23] However, in contrast to **12c**, reactions of **12d** and **12e** with enol ethers failed.[1f,3] The formation of azulenes from the pentamethylcyclohepta[*b*]furan-2(2*H*)-one **12e**, the X-ray crystal structure of which shows that it is no longer planar due to the Me group crowding effect,[1f] turned out to be much less efficient, partially attributable to the Me group strain of the formed azulenes **34** and **39** which makes them extremely sensitive to the exposure to air, so that isolation and purification became difficult.[22] The alkyl substituent at C(1) seems to be especially detrimental to these polymethylazulenes, since the 4,5,6,7,8-pentamethylazulene (**40**) proved to be distinctly more stable than **37** or **39**.

In conclusion, we presented an improved, short and versatile route to polyalkylated azulenes which allows almost total flexibility in the design of the alkyl substitution pattern at the seven-membered ring as well as at the five-membered ring of the azulenes. We showed that alkylcyclohepta[*b*]furan-2(2*H*)-ones **12** serve as versatile precursors for corresponding alkylazulenes. The substitution pattern at the seven-membered ring is determined by that of the easily accessible starting phenol components **8**. Thermal reactions of the azulene precursors **12** with enol ethers or in situ generated enamines, preferably with pyrrolidine as amino component, allow the concomitant introduction of alkyl substituents also at C(1) and/or C(2) at the five-membered ring part of the polymethylazulenes. Our experiments demonstrate that alkyl substituents can be introduced selectively at all C atoms of the azulene skeleton in a very flexible manner and in a few steps only–with the exception of C(3) which, however, is still open for electrophilic substitution reactions. This provides an extended and alternative access to a variety of polyalkylated azulenes, independent of alkylated tropolone, alkylpyrylium or -pyridinium precursors.

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(13) Typical procedure for the synthesis of 2-isopropyl-4,8-dimethylazulene (vetivazulene or elemazulene, **16**): In a thick-walled 15 mL Pyrex tube, equipped with a srew cap and a magnetic stirrer, 300 mg to 500 mg of 4,8-dimethylcyclohepta[*b*]furan-2(2*H*)-one (**12b**) were dissolved in 10 mL of either a mixture of anhyd toluene and *t*-BuOH (ca. 3:1 to 1:1, to enhance the solubility of **12b**) or pure *t*-BuOH. Then, 1.5–2.5 mL of enamine **15** (prepared according to ref.[14]) were added, and the tube was sealed and heated in an oil bath to 120–130 °C for 12–16 h with stirring. During this time, the color of the reaction mixture changed from orange to reddish brown or dark violet. The formation of the violet azulene **16** was directly monitored by TLC analyses of aliquot parts of the mixture (alox plates, eluant hexane). Samples were taken from the tube after cooling to r.t. (a small pressure relief was observed, due to the evolution of equimolar amounts of CO_2 during the reaction). Work-up: The reaction mixture was poured into about 50 mL of hexane and washed several times with water (to hydrolyze the excess of non-reacted enamine), successively with 5% HCl solution, and sat. $NaHCO_3$ solution. After evaporation of the volatile components in vacuo the dark-colored oily residue was filtered through a pad of aluminium oxide (or SiO_2) with hexane as eluant. The violet filtrate was collected, dried on $MgSO_4$ and concentrated. After purification by column chromatography on aluminium oxide with hexane as eluant, azulene **16** was obtained as blue-violet oil (GC purity > 95%) in typical yields of 70–80% (cf. also the similar general procedure in ref.[20d]). Selected spectroscopic data of **16**: ^{1}H NMR (300 MHz, $CDCl_3$): 7.34 [t, *J* = 10.2 Hz, H-C(6)]; 7.25 [s, H-C(1,3)]; 7.07 [d, *J* = 10.2 Hz, H-C(5,7)]; 3.30 [sept, *J* = 6.9 Hz, 1 H, *i*Pr-C(2)]; 2.88 [s, H_3C-C(4,8)]; 1.43 (d, *J* = 6.9 Hz, 6 H, *i*Pr-C(2)). ^{1}H NMR (300 MHz, C_6D_6): 7.33 (s, 2 H); 7.11 (t, *J* = 10.0 Hz, 1 H), 6.83 (d, *J* = 10.2 Hz, 2 H); 3.29 (sept, *J* = 6.9 Hz, 1 H); 2.65 (s, 6 H); 1.45 (d, *J* = 6.9 Hz, 6 H).^{13}C NMR (75 MHz, $CDCl_3$): 158.0 [C(2)], 144.6 [C(4,8)], 137.7 [C(3a,8a)], 133.5 [C(6)], 125.5 [C(5,7)], 113.5 [C(1,3)], 30.1 [d, *i*Pr-C(2)], 24.5 [Me-C(4,8)], 24.0 [q, *i*Pr-C(2)]. EI-MS: 199.0 (22), 198.0 (92, M^+), 182.9 (100, M – 15), 168.0 (55, M – 30), 165.0 (47, M – 43).

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(15) Preparations of azulenes **17** and **35** were performed analogously to the procedure described in ref.[13] Selected spectroscopic data of 2-isopropyl-4,6,8-trimethylazulene (**17**) (reddish-violet oil): ^{1}H NMR (300 MHz, $CDCl_3$): 7.17 (s, 2 H); 7.00 (s, 2 H), 3.26 (sept, *J* = 6.9 Hz, 1 H); 2.83 (s, 6 H); 2.28 (s, 3 H); 1.41 (d, *J* = 6.9 Hz, 6 H).^{1}H NMR (300 MHz, C_6D_6): 7.32 (s, 2 H); 6.82 (s, 2 H); 3.30 (sept, 1 H); 2.67 (s, 6 H); 2.30 (s, 3 H); 1.47 (d, *J* = 6.9 Hz, 6 H). ^{13}C NMR (75 MHz, $CDCl_3$): 156.5, 144.1, 143.5 136.2 (4 s), 127.2 (d), 113.4 (s), 29.9 (d), 28.4, 24.8, 23.9 (3 q). EI-MS: 212.0 (87, M^+), 197.0 (100, M – 15). Data of 2-isopropyl-4,5,7,8-tetramethylazulene (**35**) (dark-blue solid): ^{1}H NMR (300 MHz, $CDCl_3$): 7.50 (s, 1 H); 7.14 (s, 2 H), 3.25 (sept, *J* = 6.9 Hz, 1 H); 2.72 (s, 6 H); 2.51 (s, 6 H); 1.41 (d, *J* = 6.9 Hz, 6 H).^{1}H NMR (300 MHz, C_6D_6): 7.37 (s, 3 H); 3.34

(sept, 1 H); 2.58 (s, 6 H); 2.30 (s, 6 H); 1.50 (d, *J* = 6.9 Hz, 6 H). ^{13}C NMR (75 MHz, $CDCl_3$): 157.2, 142.6 (2 s), 139.7 (d), 138.6, 130.2 (2 s), 111.7, 30.0 (2 d), 26.8, 23.9, 21.1 (3 q). EI-MS: 226.0 (100, $M^{+\cdot}$), 211.0 (65, M – 15).

(16) (a) The well-established Ziegler–Hafner procedure, starting from the corresponding trimethylpyrylium salt and sodium cyclopentadienide, delivers optimized yields of **20** in the order of 45–65%: Hafner, K.; Kaiser, H. *Liebigs Ann. Chem.* **1958**, *618*, 140. (b) cf. also: *Org. Synth. Coll. Vol. V*; J. Wiley and Sons: New York, **1964**, 1088–1091. (c) For NMR data, see also: Braun, S.; Kinkeldei, J. *Tetrahedron* **1977**, *33*, 1827–1832; and references therein.. (d) Cf.: Matsubara, Y.; Takekuma, S.; Yokoi, K.; Yamamoto, H.; Nozoe, T. *Bull. Chem. Soc. Jpn.* **1987**, *60*, 1415. (e) Collins, M. J.; Sternhell, S.; Tansey, C. W. *Aust. J. Chem.* **1990**, *43*, 1541. (f) Fallahpour, R.-A.; Hansen, H.-J. *Helv. Chim. Acta* **1995**, *78*, 1419.

(17) Hafner's synthesis (cf. ref.[16a]) leads to badly separable mixtures of 1,4,6,8- and 2,4,6,8-tetramethylazulene (**23**, and **25**, respectively): Anderson, A. G.; Anderson, R. G.; Hollander, G. T. *J. Org. Chem.* **1965**, *30*, 131; cf. also ref.[5c].

(18) For further literature, including spectroscopic characterizations, see: (a) Chen, Y.; Kunz, R. W.; Uebelhart, P.; Weber, R. H.; Hansen, H.-J. *Helv. Chim. Acta* **1992**, *75*, 2447. (b) Fallahpour, R. A.; Hansen, H.-J. *Helv. Chim. Acta* **1992**, *75*, 2210. (c) Rippert, A. J. *Ph. D. Thesis*; University of Zürich: Switzerland, **1994**.

(19) Cf. ref.[1g] and references cited therein.

(20) For the preparation of pyrrolidine enamines from aminals cf.: (a) Mannich, G.; Davidsen, H. *Ber. Deutsch. Chem. Ges.* **1936**, *69*, 2106. (b) Opitz, G.; Hellmann, H.; Schubert, H. W. *Liebigs Ann. Chem.* **1959**, *623*, 112. (c) Igarashi, M.; Tada, M. *J. Heterocyclic Chem.* **1995**, *32*, 807; and references therein. (d) *In situ aminal thermolysis* (general method): Finely powdered, dry K_2CO_3 (1.2–2 mol equiv) was suspended in toluene, and pyrrolidine (2 mol equiv) was added. The aldehyde (1 mol equiv) was added with stirring at 0–5 °C and the suspension stirred for 12 h at r.t. (inert gas atmosphere). After filtration (or centrifugation) the slightly yellowish 'aminal solutions' were used without further purification. The cyclohepta[*b*]furan-2(2*H*)-ones **12** were dissolved in TEGDME (or NMP or toluene, respectively) and heated with stirring together with about 5–7 mol equiv of the 'aminal solution' to 120–140 °C in a stainless steel autoclave or Schlenk flask, respectively. Within 12–36 h the mixture changed the color from yellow to reddish brown and finally to violet with a slight evolution of gas (CO_2). The formation of the azulenes was monitored by TLC analyses after acidic work-up of aliquot parts of the product mixture. Finally, the mixtures were poured in diluted HCl solution (pH ca. 4–5) and the organic phase dissolved in hexane. The intensely blue-green to red-violet colored organic layers were washed several times with diluted HCl solutions and brine, and filtered through a pad of silica gel or alox. The now blue or violet organic phases were dried ($NaSO_4$) and the solvent removed. The azulenes were subsequently purified by column chromatography on alox (basic, act. IV) or on silica gel with hexane as eluent.

(21) (a) Hafner, K. *Angew. Chem.* **1958**, *70*, 419. (b) Hafner, K.; Stephan, A.; Bernhard, C. *Liebigs Ann. Chem.* **1961**, *650*, 42. (c) Hafner, K.; Stephan, A.; Bernhard, C. *Liebigs Ann. Chem.* **1961**, *650*, 62.

(22) For azulene formation from **12e** by cycloaddition with itself or with other cyclohepta[*b*]furan-2(2*H*)-ones such as **12a** or **12c**, see ref.[1f]

(23) Data of selected azulenes: For **14**, **33** and **34**, see ref.[4]. NMR data (standard conditions: 300/75.5 MHz, in $CDCl_3$/TMS): 1,4,6,8-Tetramethylazulene(**23**): (violet-blue cyrstals) ^{1}H NMR: 7.44 [d, ^3J {H-C(3)} = 4 Hz, H-C(2)]; 7.24 [d, ^3J {H-C(2)} = 4 Hz, H-C(3)]; 6.86 [br s, H-C(5,7)]; 3.02 [s, CH_3-C(8)]; 2.81 [s, CH_3-C(4)]; 2.56 [br s, 6 H, CH_3-C(1), CH_3-C(6)]. ^{13}C NMR: 147.1 [C(8)], 145.7 [C(6)]; 144.9 [C(4)]; 136.7 [C(3a)]; 136.5 [C(2)]; 132.9 [C(8a)]; 127.7 [C(7)]; 126.8 [C(1)]; 125,6 [C(5)]; 114.6 [C(3)]; 28.4 [*C*H$_3$-C(8)]; 27.7 [*C*H$_3$-C(6)]; 25.3 [*C*H$_3$-C(4)]; 19.7 [*C*H$_3$-C(1)]. EI-MS (GC-MS): 184 (100, $M^{+\cdot}$), 169 (85, $[M - CH_3]^+$). 2,4,6,8-Tetramethylazulene (**25**): (blue-violet crystals) ^{1}H NMR: 7.12 [s, H-C(1,3)]; 7.02 [s, H-C(5,7)]; 2.82 [s, H$_3$C-C(4,8)]; 2.61, 2.598 [2 s, H$_3$C-C(6), H$_3$C-C(2)]. ^{13}C NMR: 145.0, 144.0, 143.0, 136.5 [4 q, C(2,3a/8a,4/8,6)]; 127.2 [d, H-C(5/7)]; 116.3 [d, H-C(5/7)]; 28.4 [q, H$_3$*C*-C(6)]; 24.8 [q, H$_3$*C*-C(4/8)]; 16.4 [q, H$_3$*C*-C(2)]. EI-MS (GC-MS): 184 (100, $M^{+\cdot}$), 169 (65, $[M - CH_3]^+$). 2-Ethyl-4,6,8-trimethylazulene (**28**): ^{1}H NMR (taken from the 1:1 mixture with known **27**): 7.12 [*s*, H-C(1,3)]; 6.99 [(H-C(5,7)]; 3.03 [q, *J* = 7.4 Hz, Me-C*H*$_2$-C(2)]; 2.81 [s, CH_3-C(4,8)]; 2.60 [s, CH_3-C(6)]; 1.32 [t, *J* = 7.4 Hz, C*H*$_3$-CH$_2$-C(2)]. EI-MS (GC-MS): 198 (100, M^+), 183 (75, $[M - CH_3]^+$). 1-Ethyl-4,6,8-trimethylazulene (**30**): ^{1}H NMR: 7.52 [d, ^3J = 4 Hz, H-C(2)]; 7.28 [d, *J* = 4 Hz, H-C(3)]; 6.86 [br s, H-C(5,7)]; 3.25 (q, *J* = 7.4 Hz, *H*$_2$CCH$_3$); 2.98, 2.80, 2.53 (3 s, 3 CH_3); 1.36 (t, *J* = 7.4 Hz, H$_2$CC*H*$_3$). ^{13}C NMR: 146.7, 145.6, 144.9, 136.8 (4s, arom C); 134,6 [d, H-C(2)]; 133.8 132.0 (2 s, arom. C); 128.1, 125.9, 115.1 (3 d, H-C); 28.4, 27.5, 25.5 (3 q, CH_3); 25.3 (t, C*H*$_2$CH$_3$); 17.1 (q, CH_3). EI-MS (GC-MS): 198 (35, $M^{+\cdot}$), 183 (100, $[M - CH_3]^{+\cdot}$). 1-Isopropyl-4,6,8-trimethylazulene (**32**): (blue oil) ^{1}H NMR: 7.69 [d, *J* = 4.2 Hz, H-C(2)]; 7.33 [d, *J* = 4.2 Hz, H-C(3)]; 6.98, 6.88 [2 s, H-C(5), H-C(7)]; 3.91 [sept, *J* = 6.7 Hz, *H*-C(CH$_3$)$_2$]; 3.03, 2.82, 2.54 (3 s, 3 CH_3); 1.38 [d, *J* = 6.7 Hz, H-C(C*H*$_3$)$_2$]. ^{13}C NMR: 146.2, 145.3, 144.8, 139.2, 136.7 (5 s), 131.8 (d), 130.9 (s); 128.5, 126.0, 115.5 (3 d, arom C-H); 28.5 [d, H-*C*(CH$_3$)$_2$]; 28.3, 28.1, 26.0, 25.9, 25.6 (5 q, CH_3). EI-MS (GC-MS): 212 (25, $M^{+\cdot}$), (100, $[M - CH_3]^+$). 4,5,7,8-Tetramethylazulene (**36**) (blue oil): ^{1}H NMR: 7.70 [t, *J* = 4.0 Hz, H-C(2)]; 7.66 [s, H-C(6)]; 7.39 [d, *J* = 4.0 Hz, H-C(1,3)]; 2.83 (s, 2 CH_3); 2.60 (s, 2 CH_3). ^{13}C NMR: 144.8 [s, C(3a,8a)]; 141,3 [d, H-C(6)]; 138.4 [s, C(4,8)]; 133.3 [d, H-C(2)]; 130,2 [s, C(5,7)]; 114.2 [d, H-C(1,3)]; 26.8, 21.4 (2 q). EI-MS (GC-MS): 184 (100, $M^{+\cdot}$), 169 (85, $[M - CH_3]^+$). 1,4,5,7,8-Pentamethylazulene (**37**): ^{1}H NMR: 7.60 [d, *J* = 4.1 Hz, H-C(2)]; 7.37 [d, *J* = 4.1 Hz, H-C(3)]; 2.79, 2.60, 2.54 (3 s, CH_3); 2.33 (s, 2 CH_3). ^{13}C NMR: 146.6, 143.8 [2 q, C(3a), C(8a)]; 140.8 [d, H-C(6)]; 140.0 (q, arom C); 138.1 [d, H-C(2)]; 136.5, 134.7, 130.0, 128.9 (4 q, arom C), 114.1 [d, H-C(3)]; 27.2, 26.4, 23.1, 21.4, 20.5 (5 q, CH_3). 1-Isopropyl-4,5,7,8-tetramethylazulene (**38**): (dark blue oil) ^{1}H NMR: 7.72 [d, *J* = 4.4 Hz, H-C(2)]; 7.44 [s, H-C(6)]; 7.27 [d, *J* = 4.4 Hz, H-C(3)]; 3.80 [sept, *J* = 6.9 Hz, *H*-C(CH$_3$)$_2$]; 2.83, 2.76 (2 s, CH_3); 2.51 (s, 2 CH_3); 1.37 [d, *J* = 6.7 Hz, H-C(C*H*$_3$)$_2$]. EI-MS (GC-MS): 226 (30, $M^{+\cdot}$), 211 (100, $[M - CH_3]^{+\cdot}$). 4,5,6,7,8-Pentamethylazulene (**40**)[1f] (blue crystals): ^{1}H NMR: 7.56 [t, *J* = 4.3 Hz, H-C(2)]; 7.25 [d, *J* ~ 4 Hz, H-C(1,3)]; 2.84 (br s, 6 H, 2 CH_3); 2.52 (s, 3 H, CH_3); 2.47 (s, 6 H, 2 CH_3). ^{13}C NMR: 145.3, 144.4, 137.6 (3 s); 132.1 [d, C(2)]; 130.5 (s); 113.9 [d, C(1,3)]; 24.5, 22.7, 22.5 (3 q). 1,4,5,6,7,8-Hexamethylazulene (**39**): (blue-violet oil) ^{1}H NMR: 7.20 [d, *J* = 3.9 Hz, H-C(2)]; 6.99 [d, *J* = 3.9 Hz, H-C(3)]; 2.75, 2.70, 2.68, 2.37 (4 s, 4 CH_3); 2.33 (br s, 2 CH_3).