FORMATION OF NOVEL CAGE COMPOUNDS VIA ENDO-[3 + 2] CYCLOADDUCTS BETWEEN THIAZOLIUM N-METHYLIDES AND METHYLENECYCLOPROPENES

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Thiazolium N-phenacylide and N-dicyanomethylide react with a methylenecyclopropene bearing an aryl group on the 4-position to give novel cage compounds, 6,8thiazapentacyclo[$6.3.1.0^{1,10}.0^{5,12}.0^{7,11}$]dodecenes. The reaction proceeds via an intramolecular Diels-Alder reaction of the initially formed endo-[3 + 2] cycloadducts, followed by a hydrogen shift.

Methylenecyclopropenes undergo cycloaddition reactions with a variety of 1,3-dipoles.¹⁻⁷ The modes of these reactions depend not only on the nature of 1,3-dipoles, but also on the substituents at the 4-position of methylenecyclopropenes.⁸ We have recently found that benzothiazolium N-phenacylide adds to the cyclic double bond of certain methylenecyclopropenes to give endo-[3 + 2] cycloadducts in good yields⁹: This is the first example for the formation of stable [3 + 2] cycloadducts in the reactions of 1,3-dipoles with methylenecyclopropenes. If a similar endo-[3 + 2] cycloadduct is formed in the reaction of a thiazolium N-methylide with a methylenecyclopropene bearing an appropriate functional group at the 4-position, a cage compound might be expected to be formed via an intramolecular cyclization reaction of the endo-[3 + 2] cycloadduct, whose Dreiding model indicates that the carbons at the 3- and 8-positions are located closely enough to be linked¹⁰ (Scheme 1).



This expectation is now realized: We wish to report here the formation of novel cage compounds from the reaction of thiazolium N-phenacylide 1 and N-dicyanomethylide 2 with 2-phenyl-2-(2,3-diphenyl-2-cyclopropenylidene)acetonitrile 3 and 9-(2,3-diphenyl-2-cyclopropenylidene)anthrone 4, which reacted with benzothiazolium N-phenacylide to afford the corresponding endo-[3 + 2] cycloadducts as the sole products.⁹

First, we have investigated the reaction of $\underline{1}$ with $\underline{3}$. To a solution of 3-phenacylthiazolium bromide (622 mg, 2.2 mmol) and $\underline{3}^{11}$ (610 mg, 2.0 mmol) in dry THF (100 mL) was added NEt3 (221 mg, 2.2

mmol) at 0° C, with stirring, under nitrogen. After the reaction mixture was stirred at 0° C for 2 h, and then at room temperature for 3 h, the precipitated triethylammonium bromide (quantitative) was removed by filtration. The filtrate was concentrated in vacuo to leave a residue, which was purified by chromatography on silica gel using benzene as an eluent to give 807 mg (79%) of the 1:1 adduct 5, mp 150-152°C (dec), as pale yellow prisms. On the basis of spectral data¹² as well as of the chemical conversion described below, 5 was assigned as the expected endo-[3 + 2] cycloadduct. Upon heating in THF under reflux for 3 h, 5 was transformed into two isomeric cage compounds 6, mp 177-178°C (dec), and 7, mp 170-172°C (dec), in 51 and 31% yields, respectively.





On the other hand, the methylide 2^{13} reacted with 3 to give directly analogous two cage compounds. A solution of 2 (298 mg, 2.0 mmol) and 3 (610 mg, 2.0 mmol) in dry THF (30 mL) was stirred at room temperature for 4 days until 3 was completely consumed. The reaction mixture was concentrated in vacuo to leave a residue, which was chromatographed on silica gel using benzene as an eluent to give 460 mg (51%) and 329 mg (36%) of the 1:1 adducts 8, mp 274-276°C (dec), and 9, mp 259-260°C (dec), respectively.

On the basis of spectral data,¹⁴ each of isomers <u>6</u>, <u>7</u> or <u>8</u>, <u>9</u> was assigned as a stereoisomerc cage compound arising from an intermediary Diels-Alder adduct like <u>A</u>, followed by a hydrogen shift. A few Diels-Alder reactions involving aromatic nucleus as a part of diene component have been reported in intermolecular reactions.¹⁵ In the ¹H NMR spectra the 12-hydrogen in each higher melting cage compound appeared at lower field than that in each lower melting one. An inspection of the Dreiding models

indicates that the 12-hydrogen in $\underline{6}$ or $\underline{8}$ is located in the deshielding cone of the cyano group on the 2-position. Thus it can be concluded that the higher melting cage compound is $\underline{6}$ or $\underline{8}$ and the lower melting one is 7 or 9, respectively.

The reaction of 2 with the methylenecyclopropene 4^{16} in refluxing THF for 2 h gave a 76% yield of



Scheme 3

the cage compound <u>10</u>, mp 192-194^oC (dec), whose structure was again confirmed on the basis of spectral data.¹⁷ It is evident that the reaction proceeds via an initial formation of the endo-[3 + 2] cyclo-adduct <u>B</u>, followed by an intramolecular Diels-Alder reaction to yield <u>C</u>, which is converted to <u>10</u> by a hydrogen shift (Scheme 3).

References

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- 10. The distance between the C_3 and C_8 was estimated at ca. 2.4 Å by an inspection of the Dreiding model.
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- 12. All new compounds in this paper gave satisfactory elemental analyses.

<u>5</u>: IR (KBr) 2210, 1680 cm⁻¹; ¹H NMR (CDCl₃) δ 5.02, 5.97 (each 1H, d, =C<u>H</u>, J=5.0 Hz), 6.13 (1H, s, \geq C<u>H</u>), 6.77-8.15 (21H, m, \geq C<u>H</u> + Ar<u>H</u>); ¹³C NMR (CDCl₃) δ 46.7, 50.3 (each s, quat. <u>C</u>), 72.5, 81.0 (each d, tert. <u>C</u>), 195.6 (<u>C</u>=0); MS m/e 508 (M⁺).

- 13. V. Boekelheide and N. A. Fedoruk, J. Am. Chem. Soc., <u>90</u>, 3830 (1968).
- 14. <u>6</u>: colorless prisms; IR (KBr) 2240, 1675 cm⁻¹; ¹H NMR (CDCl₃) δ 4.21 (1H, s, 2-<u>H</u>), 4.41 (1H, d, 12-<u>H</u>, J=5.0 Hz), 4.64 (1H, s, 9-<u>H</u>), 5.06 (1H, d, 5-<u>H</u>, J=5.0 Hz), 5.49 (1H, s, 7-<u>H</u>), 6.63-8.32 (19H, m); ¹³C NMR (CDCl₃) δ 28.0 (d, tert. <u>C</u>), 33.4, 37.1, 43.3 (each s, quat. <u>C</u>), 45.7, 71.5, 80.4 (each d, tert. <u>C</u>), 195.5 (<u>C</u>=0); MS m/e 508 (M⁺).

<u>7</u>: colorless prisms; IR (KBr) 2230, 1670 cm⁻¹; ¹H NMR (CDC1₃) δ 4.07 (1H, d, 12-<u>H</u>, J=5.0 Hz), 4.68, 4.71 (each 1H, s, 2-<u>H</u>, 9-<u>H</u>), 4.97 (1H, d, 5-<u>H</u>, J=5.0 Hz), 5.18 (1H, s, 7-<u>H</u>), 7.07-8.23 (19H, m); ¹³C NMR (CDC1₃) δ 29.7 (d, tert. <u>C</u>), 29.9, 36.7, 42.4 (each s, quat. <u>C</u>), 45.4, 74.1, 74.6, 81.7 (each d, tert. <u>C</u>), 195.8 (<u>C</u>=0); MS m/e 508 (M⁺).

<u>8</u>: colorless prisms; IR (KBr) 2230 cm⁻¹; ¹H NMR (CDC1₃) δ 4.29 (1H, s, 2-<u>H</u>), 4.83 (1H, d, 12-<u>H</u>, J= 5.0 Hz), 5.17 (1H, s, 7-<u>H</u>), 5.19 (1H, d, 5-<u>H</u>, J=5.0 Hz), 6.65-7.60 (14H, m); ¹³C NMR (CDC1₃) δ 27.9 (d, tert. <u>C</u>), 32.9, 41.7, 44.5 (each s, quat. <u>C</u>), 45.4 (d, tert. <u>C</u>), 63.3 (s, quat. <u>C</u>), 70.1, 79.7 (each d, tert. <u>C</u>); MS m/e 454 (M⁺).

<u>9</u>: colorless prisms; IR (KBr) 2230 cm⁻¹; ¹H NMR (CDC1₃) δ 4.47 (1H, d, 12-<u>H</u>, J=5.0 Hz), 5.03 (2H, s, 2-<u>H</u>, 7-<u>H</u>), 5.14 (1H, d, 5-<u>H</u>, J=5.0 Hz), 7.05-7.77 (14H, m); ¹³C NMR (DMSO-d₆) δ 27.8, 28.6, 39.5, 42.9, 44.8, 64.6, 71.7, 81.5; MS m/e 454 (M⁺).

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- 17. <u>10</u>: pale green prisms; IR (KBr) 3500, 2230 cm⁻¹; ¹H NMR (DMSO-d₆) δ 4.96 (1H, d, 12-<u>H</u>, J=5.0 Hz), 5.53 (1H, s, 7-<u>H</u>), 5.54 (1H, d, 5-<u>H</u>, J=5.0 Hz), 6.26-8.63 (18H, m, Ar<u>H</u> + 0<u>H</u>); ¹³C NMR (DMSO-d₆) δ 25.0, 38.0, 41.4, 46.2, 62.7, 66.9, 79.0; MS m/e 531 (M⁺).

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