# Synthesis of Adamantane Derivatives. 52.[1] 1,3-Dipolar Cycloaddition Reactions of 1-Azidoadamantane. Reactivity, Regioselectivity, and Carbon-13 Nuclear Magnetic Resonance Spectra of 1-(1-Adamantyl)-$\Delta^2$-1,2,3-triazolines and -1*H*-1,2,3-triazoles

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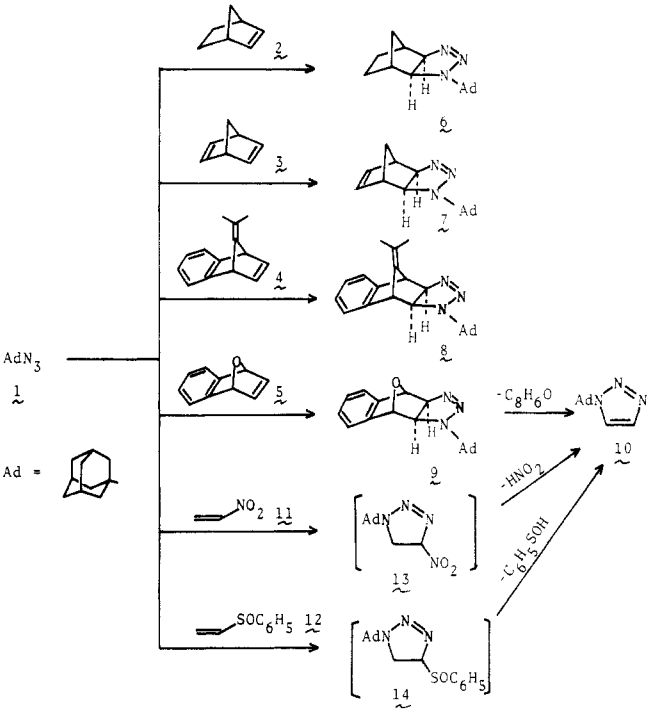
The 1,3-dipolar cycloadditions of 1-azidoadamantane (**1**) with various olefinic and acetylenic dipolarophiles are described. As olefinic dipolarophiles, strained olefins such as **2–5** and electron-poor olefins such as **11**, **12**, **15**, and **18** gave the corresponding adducts, **6–9**, **16**, a retrocycloaddition product **10**, and aromatized products **10**, **21**, and **22**. As acetylenic dipolarophiles, phenylacetylene (**23**) and propargyl alcohol (**30**) afforded both regioisomers of the adducts **21** and **22** and adducts **31** and **32**, respectively. Adamantylacetylene (**24**) and propiolate esters **27** and **33** gave only 4-substituted triazoles **25**, **28**, and **34**. Symmetrical acetylenes **36–39** also gave adducts **40–43**. $^{13}C$ NMR data of some of these triazolines and triazoles were reported also.

Organic azides are well-known as excellent synthetic starting materials for various nitrogen-containing organic molecules; however, synthetic studies utilizing bridgehead azides seem to be quite limited:[2] this might be due to the lack of a facile and efficient method for introduction of the azido group at bridgehead positions. In view of this we have recently developed a convenient and efficient synthesis of 1-azidoadamantane and related bridgehead azides.[3] Among important reaction types of azides[4] 1,3-dipolar cycloadditions to dipolarophiles seem not to have been studied extensively as those for 1-azidoadamantane,[5,6] though reduction,[7] photolysis,[8] and acidolysis[3,9] have been reported. This paper deals with the 1,3-dipolar cycloaddition reactivity and regioselectivity of 1-azidoadamantane and carbon-13 nuclear magnetic resonance spectra of some 1-(1-adamantyl)-$\Delta^2$-triazolines and -1*H*-triazoles.

## Results and Discussion

**Reactions of 1-Azidoadamantane (1) with Olefinic Dipolarophiles.** The reactions of 1-azidoadamantane (**1**) with strained olefins such as norbornene (**2**), norbornadiene (**3**), 7-isopropylidenebenzonorbornadiene (**4**), and 7-oxabenzonorbornadiene (**5**) proceeded smoothly on heating (25–110 °C) in toluene to afford the corresponding 1,3-dipolar cycloadducts, **6–9**, respectively, in good yields (Scheme I, Table I). The structural proofs of these products were based on elemental analyses and spectral data (Tables II and III). The exo configuration of the adducts **6–9** was supported by the absence of couplings between the bridgehead protons and vicinal triazoline protons, respectively (Table II). The reaction of **1** with **5** at 110 °C afforded 1-(1-adamantyl)-1,2,3-triazole (**10**) in 70.7% yield as a retro-Diels–Alder product of the primary

Scheme I




adduct **9**. Nitroethylene (**11**)[10] and phenyl vinyl sulfoxide (**12**),[11] known as the acetylene synthon, reacted with **1** to afford directly triazole **10** in good yields, though the primary adducts such as **13** and **14** could not be isolated.

The reaction of **1** with ethyl acrylate (**15**) proceeded even at 25 °C to afford exclusively 4-substituted triazoline **16** in good yields. The assigned regiochemistry was supported by $^1H$ and $^{13}C$ NMR spectra (Tables II and III). In $^1H$ NMR spectra, the chemical shifts and coupling constants of the $\Delta^2$-1,2,3-triazoline ring protons were quite similar to those reported for the corresponding adduct of phenyl azide.[12] $^{13}C$ NMR spectra revealed a characteristic triplet at $\delta$ 61.9 (1 C) assignable to $C_5$, supporting the structure **16**. The observed regiochemistry was also supported by the frontier molecular orbital (FMO) theory[13] as well as

(1) Part 51: Sasaki, T.; Eguchi, S.; Suzuki, T. *Heterocycles* **1980**, *15*, 251.
(2) For a general review, see: Patai, S., Ed. "The Chemistry of the Azido Group"; Interscience: New York, 1971.
(3) Sasaki, T.; Eguchi, S.; Katada, T.; Hiroaki, O. *J. Org. Chem.* **1977**, *42*, 3741.
(4) Reference 2, p 333.
(5) Only the reaction of 1-azidoadamantane with 4-homoadamantene has been reported, which gave a nitrogen-extrusion product, homoadamantano[4,5-*b*]-1-(1-adamantyl)aziridine: Sasaki, T.; Eguchi, S.; Hattori, S. *Heterocycles* **1978**, *11*, 235.
(6) For cycloadditions to nitrilium salts, see: Quast, H.; Bieber, L. *Tetrahedron Lett.* **1976**, 1485.
(7) Sasaki, T.; Eguchi, S.; Toru, T. *Bull. Chem. Soc. Jpn.* **1969**, *42*, 3613.
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(9) Margosian, D.; Sparks, D.; Kovacic, P. *J. Chem. Soc., Chem. Commun.* **1980**, 275.
(10) Buckley, G. D.; Scaife, C. W. *J. Chem. Soc.* **1947**, 1471.
(11) Paquette, L. A.; Moerck, R. E.; Harirchian, B.; Magnus, P. D. *J. Am. Chem. Soc.*, **1978**, *100*, 1597.
(12) Huisgen, R.; Szeimies, G.; Möbius, L. *Chem. Ber.* **1966**, *99*, 475.
(13) For a recent review, see: Fleming, I. "Frontier Orbitals and Organic Chemical Reactions"; Wiley: New York, 1976.

0022-3263/81/1946-1800$01.25/0 

Table I. 1,3-Dipolar Cycloadditions of 1-Azidoadamantane (1) with Olefinic and Acetylenic Dipolarophiles[a]

| dipolarophile (molar ratio to 1) | reaction temp, °C | time, h | product (yield, %) | mp, °C (recryst solv) |
|---|---|---|---|---|
| **2** (1.67) | 110 | 72 | **6** (70.0) | 118-119 (*n*-hexane) |
| **3** (1.67) | 70 | 168 | **7** (39.5) | 108-109 (*n*-hexane-$CH_2Cl_2$) |
| **4** (1.00) | 25 | 170 | **8** (63.8) | 151-153 (*n*-hexane) |
| **5** (1.00) | 25 | 500 | **9** (100) | 137-139 (toluene) |
| **5** (1.41) | 110 | 9 | **10** (70.7) | 43-46[c] |
| **11** (0.81) | 110 | 24 | **10** (72.9) | |
| **12** (2.16) | 110 | 72 | **10** (88.0) | |
| **15** (5.00) | 25 | 336 | **16** (84.6) | 55-57 (*n*-hexane) |
| **18** (1.15) | 60 | 500 | **21** (30.1)[b] | 188-189 (*n*-hexane-$CH_2Cl_2$) |
| | | | **22** (2.5)[b] | 205-206 (*n*-hexane-$CH_2Cl_2$) |
| **18** (1.15) | 110 | 35 | **21** (65.7),[b] **22** (5.7)[b] | |
| **23** (1.97) | 110 | 35 | **21** (21.0),[b] **22** (59.6)[b] | |
| **24** (1.00) | 110 | 30 | **25** (67.0) | 287-289 (*n*-hexane) |
| **27** (1.52) | 110 | 11 | **28** (83.9) | 100-102 (*n*-hexane) |
| **30** (7.35) | 110 | 5 | **31** (80.0)[b] | 99-100 (*n*-hexane) |
| | | | **32** (11.2)[b] | 169-171 (*n*-hexane) |
| **33** (1.40) | 110 | 50 | **34** (77.0) | 98-99 (*n*-hexane) |
| **36** (1.07) | 110 | 24 | **40** (77.0) | 115-116 (*n*-hexane-$CH_2Cl_2$) |
| **37** (1.10) | 110 | 90 | **41** (32.3) | 218-220 ($CHCl_3$-$CH_3OH$) |
| **38** (1.00) | 110 | 500 | **42** (17.4) | 215-217 ($C_2H_5OH$) |
| **39** (1.10) | 110 | 180 | **43** (4.6) | 193-194 (*n*-hexane-$CHCl_3$) |

[a] Toluene was used as a solvent. [b] Purified on a silica gel column eluted with $CH_2Cl_2$-$CH_3OH$ or $CH_2Cl_2$-$CH_3CO_2C_2H_5$. [c] Distills at 120 °C (0.3 mm).

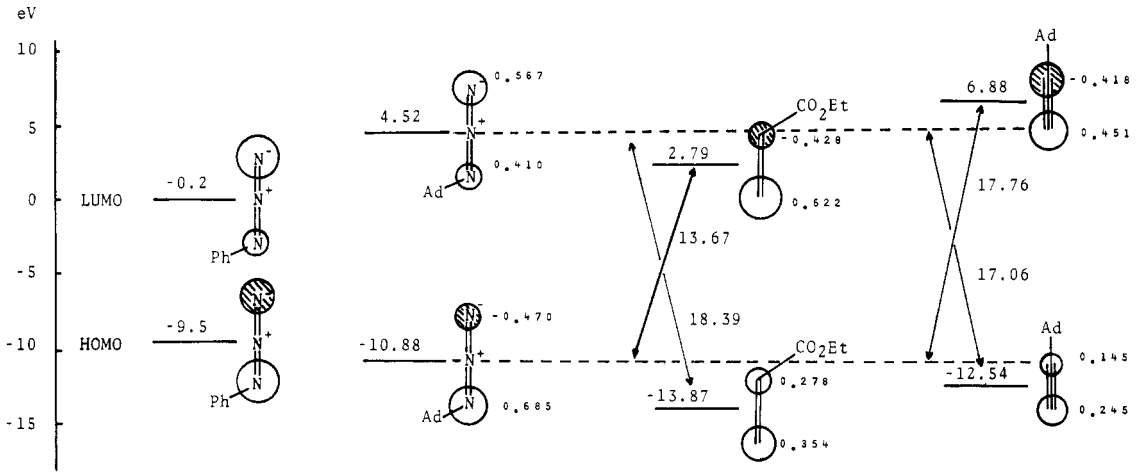



**Figure 1.** Frontier orbitals of phenyl azide,[23] 1-azidoadamantane (**1**), ethyl acrylate (**15**), and 1-adamantylacetylene (**24**).

by the results calculated (CNDO/2 method) by using the perturbation equation (eq 1) derived by Klopman[14] and

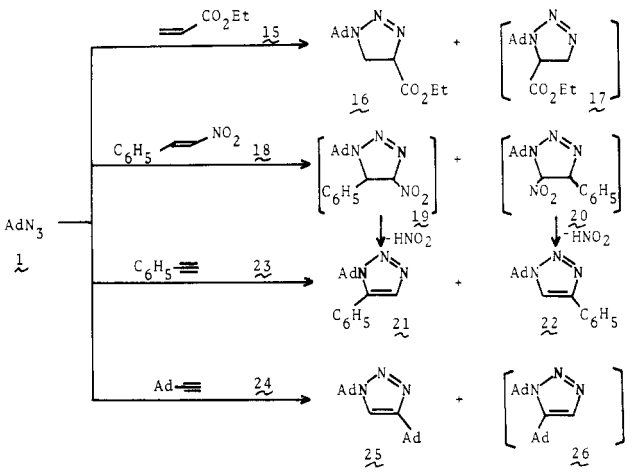
$$\Delta E = -\underset{a,b}{\sum}(q_a + q_b)\beta_{ab}S_{ab} + \underset{k,l}{\sum}\frac{Q_kQ_l}{\epsilon R_{kl}} + \underset{\text{I}}{\phantom{x}} \qquad \underset{\text{II}}{\phantom{x}}$$

$$\sum_{r}^{\text{occ}}\sum_{s}^{\text{unocc}} - \sum_{s}^{\text{occ}}\sum_{r}^{\text{unocc}} \frac{2(\sum_{ab} C_{ra}C_{sb}\beta_{ab})^2}{E_r - E_s} \quad (1)$$

III

Salem[15] (Table IV).[16] As explained in Figure 1, the dipole HOMO–dipolarophile LUMO interaction is controlling the regiochemistry which clearly favors 4-substituted adduct formation as observed.

Scheme II




The reaction of **1** with β-nitrostyrene (**18**) was carried out at 60 and 110 °C, at which both regioisomers, 5-phenyl- (**21**) and 4-phenyltriazole (**22**), were produced in 30.1:2.5

(14) Klopman, G. *J. Am. Chem. Soc.* **1968**, *90*, 223.
(15) (a) Salem, L. *J. Am. Chem. Soc.* **1968**, *90*, 543. (b) *Ibid.* **1968**, *90*, 553.
(16) The calculations were carried out by using FACOM 230-75 and M-200 computers at Nagoya University Data Processing Center. The geometries of the molecules necessary for CNDO/2 calculations were constructed by using standard bond lengths and angles. In eq 1, the value of dielectric constant of $\epsilon = 2.194$ for toluene (110 °C) was used. The value of interatomic distance, $R_{CN}$, was assumed as 1.75 Å, and hence, the values of resonance integral, $\beta_{CN}$, and overlap integral, $S_{CN}$, were taken to be 5.83 and 0.255, respectively: Pople, J. A.; Beveridge, D. L. "Approximate Molecular Orbital Theory"; McGraw-Hill: New York, 1970.

Table II. Analytical Data for 1-(1-Adamantyl)-$\Delta^2$-1,2,3-triazolines and -1*H*-triazoles

| compd | IR,[a] cm$^{-1}$ | $^1$H NMR,[b] $\delta$ | molec formula | anal. calcd (found) C | H | N |
|---|---|---|---|---|---|---|
| 6 | 1630, 1480, 1450, 1075 | 4.27 (d, 1, $J$ = 10.0), 3.33 (d, 1, $J$ = 10.0), 2.67 (br s, 1), 2.5-1.0 (m, 22) | $C_{17}H_{25}N_3$ | 75.23 (75.22) | 9.28 (9.17) | 15.48 (15.34) |
| 7 | 3080, 1610, 1470, 1450, 1075 | 6.19 (dd, 1, $J$ = 5.0, 3.0), 6.01 (dd, 1, $J$ = 5.0, 3.0), 4.64 (d, 1, $J$ = 10.0), 3.74 (d, 1, $J$ = 10.0), 3.32 (br s, 1), 2.94 (br s, 1), 2.3-1.1 (m, 17) | $C_{17}H_{23}N_3$ | 75.79 (75.76) | 8.61 (8.57) | 15.60 (15.67) |
| 8 | 1460, 1095, 970 | 7.3-7.0 (m, 4), 4.67 (d, 1, $J$ = 10.0), 4.22 (s, 1), 3.79 (s, 1), 3.75 (d, 1, $J$ = 10.0), 2.32-1.12 (m, 15), 1.64 (s, 6) | $C_{24}H_{29}N_3$ | 80.41 (80.53) | 7.87 (7.78) | 11.72 (11.69) |
| 9 | 1460, 1100, 960 | 7.4-7.0 (m, 4), 5.66 (s, 1), 5.24 (s, 1), 4.88 (d, 1, $J$ = 9.0), 3.88 (d, 1, $J$ = 9.0), 2.4-1.6 (m, 15) | $C_{20}H_{23}N_3O$ | 74.74 (75.04) | 7.21 (7.25) | 13.07 (12.77) |
| 10 | 1450, 1085, 780 | 7.66 (s, 2), 2.4-1.7 (m, 15) | $C_{12}H_{17}N_3$ | 70.90 (71.08) | 8.43 (8.35) | 20.67 (20.70) |
| 16 | 1740, 1470, 1200, 1090 | 4.84 (dd, 1, $J$ = 11.2, 12.8),[c] 4.25 (q, 2, $J$ = 7.0), 3.55 (dd, 1, $J$ = 11.2, 10.2),[c] 3.31 (dd, 1, $J$ = 10.1, 12.8), 2.3-1.55 (m, 15) | $C_{15}H_{23}N_3O_2$ | 64.95 (64.99) | 8.36 (8.34) | 15.15 (15.21) |
| 21 | 3050, 1480, 1450, 760 | 7.50 (s, 1), 7.6-7.3 (m, 5), 2.4-1.5 (m, 15) | $C_{18}H_{21}N_3$ | 77.38 (77.44) | 7.58 (7.66) | 15.04 (14.98) |
| 22 | 3110, 3060, 1420, 770 | 7.82 (s, 1), 8.0-7.2 (m, 5), 2.4-1.5 (m, 15) | $C_{18}H_{21}N_3$ | 77.38 (77.62) | 7.58 (7.68) | 15.04 (15.16) |
| 25 | 1470, 1320, 1030 | 7.07 (s, 1), 2.4-1.1 (m, 30) | $C_{22}H_{31}N_3$ | 78.29 (78.36) | 9.26 (9.45) | 12.45 (12.19) |
| 28 | 3130, 1725, 1420, 1200 | 8.15 (s, 1), 3.93 (s, 3), 2.4-1.7 (m, 15) | $C_{14}H_{19}N_3O_2$ | 64.35 (64.07) | 7.33 (7.13) | 16.08 (15.93) |
| 29 | 1735, 1450, 1040, 770 | 8.17 (s, 1), 3.92 (s, 3), 2.6-1.7 (m, 15) | $C_{14}H_{19}N_3O_2$ | 64.35 (64.55) | 7.33 (7.40) | 16.08 (15.80) |
| 31 | 3200, 1450, 1150, 1015 | 7.62 (s, 1), 4.78 (s, 2), 3.32 (s, 1),[d] 2.5-1.7 (m, 15) | $C_{13}H_{19}N_3O$ | 66.92 (66.73) | 8.21 (8.19) | 18.01 (18.30) |
| 32 | 3250, 1455, 1240, 730 | 7.52 (s, 1), 4.88 (s, 2), 2.90 (s, 1),[d] 2.6-1.7 (m, 15) | $C_{13}H_{19}N_3O$ | 66.92 (67.20) | 8.21 (8.26) | 18.01 (17.74) |
| 34 | 3160, 1720, 1230, 1040 | 8.19 (s, 1), 4.45 (q, 2, $J$ = 7.5), 2.47-1.67 (m, 15), 1.42 (t, 3, $J$ = 7.5) | $C_{15}H_{21}N_3O_2$ | 65.43 (65.49) | 7.69 (7.75) | 15.26 (15.37) |
| 40 | 1730, 1450, 1230, 1020 | 4.00 (s, 3), 3.92 (s, 3), 2.5-1.7 (m, 15) | $C_{16}H_{21}N_3O_4$ | 60.17 (60.12) | 6.63 (6.61) | 13.16 (13.13) |
| 41 | 3280, 1450, 1420, 1040 | 4.97 (s, 2), 4.82 (s, 2), 3.87 (s, 2),[d] 2.5-1.7 (m, 15)[e] | $C_{14}H_{21}N_3O_2$ | 63.85 (63.60) | 8.04 (7.87) | 15.96 (15.78) |
| 42 | 3060, 1450, 750, 690 | 7.5-7.0 (m, 10), 2.3-1.5 (m, 15) | $C_{24}H_{25}N_3$ | 81.09 (81.39) | 7.09 (7.24) | 11.82 (11.75) |
| 43 | 3200, 1450, 1130, 1000 | 2.6-1.5 (m, 27),[d] 1.1-0.7 (m, 6) | $C_{20}H_{33}N_3O_2$ | 69.12 (69.32) | 9.57 (9.50) | 12.09 (12.24) |
| 44 | 3100, 1740, 1460, 1250 | 7.68 (s, 1), 5.19 (s, 2), 2.07 (s, 3), 2.5-1.6 (m, 15) | $C_{15}H_{21}N_3O_2$ | 65.43 (65.68) | 7.69 (7.67) | 15.26 (15.39) |

[a] In a KBr disk. [b] In $CDCl_3$. The $J$ values are given in hertz. [c] An ABX pattern. [d] Disappeared or decreased on shaking of the sample with $D_2O$. [e] In $CDCl_3$-pyridine (3:1 v/v).

Table III. $^{13}$C NMR Chemical Shifts ($\delta$) of 1-(1-Adamantyl)-$\Delta^2$-1,2,3-triazolines and -1*H*-triazoles[a]

| compd | chemical shift $C_4$ | $C_5$ | adamantane carbons[b] | other carbons |
|---|---|---|---|---|
| 6 | 85.2 (d) | 59.1 (d) | 56.5 (s), 42.0 (t), 36.4 (t), 29.5 (d) | [43.9 (d), 41.7 (d), 32.4 (t), 26.2 (t), 25.0 (t)][c] |
| 16 | 75.6 (d) | 61.9 (t) | 56.8 (s), 41.0 (t), 36.3 (t), 29.3 (d) | [169.0 (s), 42.3 (t), 14.2 (q)][d] |
| 10 | 132.7 (d) | 119.6 (d) | 59.4 (s), 43.1 (t), 36.0 (t), 29.5 (d) | |
| 21 | 135.5 (d) | 130.2 (s)[e] | 63.1 (s), 43.0 (t), 35.8 (t), 29.7 (d) | [136.9 (s),[e] 130.6 (d), 129.2 (d), 128.1 (d)][f] |
| 22 | 146.6 (s) | 116.0 (d) | 59.5 (s), 43.0 (t), 35.9 (t), 29.5 (d) | [131.1 (s), 128.0 (d), 127.0 (d), 125.0 (d)][f] |
| 28 | 138.8 (s) | 124.2 (d) | 60.3 (s), 42.8 (t), 35.7 (t), 29.4 (d) | [161.4 (s), 51.9 (q)][g] |
| 29 | 140.6 (d) | 128.1 (s) | 64.5 (s), 41.0 (t), 35.9 (t), 29.9 (d) | [159.4 (s), 52.5 (q)][g] |
| 31 | 147.1 (s) | 118.6 (d) | 59.5 (s), 42.9 (t), 35.9 (t), 29.5 (d) | [56.0 (t)][h] |
| 32 | 134.6 (d) | 137.1 (s) | 62.6 (s), 42.1 (t), 36.0 (t), 29.7 (d) | [55.0 (t)][h] |
| 40 | 137.9 (s) | 132.2 (s) | 64.5 (s), 42.0 (t), 35.7 (t), 29.7 (d) | [162.2 (s), 160.6 (s), 54.0 (q), 52.4 (q)][i] |
| 44 | 141.7 (s) | 120.1 (d) | 59.6 (s), 43.0 (t), 35.9 (t), 29.5 (d) | [170.6 (s), 57.9 (t), 20.8 (q)][j] |

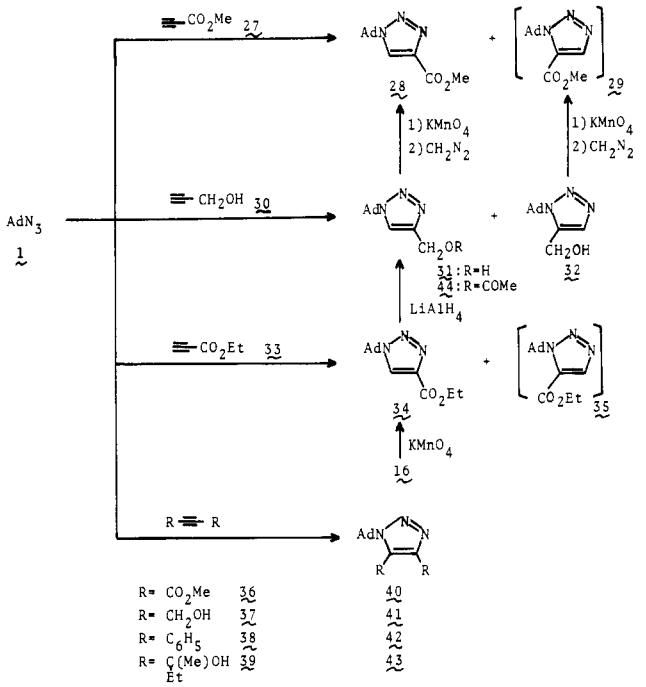
[a] Downfield from internal tetramethylsilane in $CDCl_3$. [b] In a 1:3:3:3 ratio. [c] Each for 1 C. [d] $CO_2CH_2CH_3$. [e] These assignments may be interchangeable. [f] Phenyl carbons in a 1:2:1:2 ratio. [g] $CO_2CH_3$. [h] $CH_2OH$. [i] Two $CO_2CH_3$'s. [j] $CH_2OCOCH_3$.

and 65.7:5.7 yields, respectively (Table I), but the corresponding primary adducts **19** and **20** could not be isolated (Scheme II). The regiochemical assignments were based on $^1$H NMR spectra in comparison with those reported for 1,5-diphenyltriazole ($H_4$, $\delta$ 7.87) and 1,4-diphenyltriazole ($H_5$, $\delta$ 8.20)[17] as well as FMO considerations.

Table IV. $\Delta E$ Values (eV) Calculated by Eq 1 for 16 and 17 in Toluene (110 °C)

| | I | II | III | $\Delta E$ |
|---|---|---|---|---|
| 16 | 7.341 | 0.022 | −5.581 | 1.782 |
| 17 | 7.341 | 0.062 | −5.481 | 1.922 |

Scheme III




As described above, the reactions of 1 with strained olefins and electron-deficient olefins proceeded smoothly at 25–110 °C; however, the reactions of 1 with enamines such as 1-morpholinocyclohexene, 1-pyrrolidinylcyclopentene, and 4-morpholino-2-norbornene[18] at 80–110 °C for 15–48 h did not afford the corresponding adducts.

**Reactions of 1 with Acetylenic Dipolarophiles.** The reactions of 1 with phenylacetylene (**23**) in toluene at 110 °C for 35 h afforded 1-adamantyl-5-phenyl- (**21**) and -4-phenyltriazole (**22**) in 21.0 and 59.6% yields, respectively (Scheme II). The results are contrasting to those obtained in the reaction with $\beta$-nitrostyrene (**18**), in which **21** was the predominant product. On the other hand, the reaction of phenyl azide with phenylacetylene is known to afford nearly equal amounts of 1,5- and 1,4-diphenyltriazoles.[19] Furthermore, the reaction of 1 with 1-adamantylacetylene (**24**)[20] under similar conditions gave only 1,4-bis(1-adamantyl)triazole **25** in 67% yield. These results could be rationalized by the steric hindrance between the adamantyl group and phenyl or adamantyl substituent of the acetylenes since the FMO consideration predicts equal amounts of the regioisomers (both HOMO–LUMO and LUMO–HOMO interactions are comparable; Figure 1).

The reactions of 1 with more electron-deficient, unsymmetrical acetylenes such as methyl and ethyl propiolates (**27** and **33**) gave only 4-substituted triazoles **28** (84%) and **34** (77%), respectively. However, the reaction of 1 with propargyl alcohol (**30**) afforded both regioisomers **31** and **32** in 80% and 11% yields, respectively (Table I). The interconversions of these adducts are summarized in Scheme III and support the assigned regiochemistry: potassium permanganate oxidation of **31**, followed by esterification with diazomethane, gave **28**; lithium aluminum hydride reduction of **34** yielded the adduct **31**; potassium permanganate oxidation of 4-(ethoxycarbonyl)triazoline **16** in acetone afforded **34**. Furthermore, 5-(methoxycarbonyl)triazole **29**, a regioisomer of **28**, was prepared from **32** by oxidation followed by esterification.

The reactions of 1 with symmetrical acetylenes **36–39** gave also the corresponding adducts, **40–43**, respectively, in yields depending on the reactivity of the dipolarophiles (Table I).

**Carbon-13 Nuclear Magnetic Resonance Spectra of Some of the Adducts and Their Derivatives.** In view of the fact that the chemical shifts of $H_5$ of 4-substituted triazoles and of $H_4$ of 5-substituted triazoles are quite similar as exemplified by **28–29** and **31–32**, respectively (Table II), the $^{13}C$ NMR chemical shifts of $C_4$ and $C_5$ of these triazoles as well as those of triazolines **6** and **16** are listed in Table III.[21] The assignments were based on chemical shifts, peak intensities, and proton off-resonance spectral data. The chemical shift differences between $C_4$ and $C_5$ for 4-substituted triazoles such as **22**, **28**, **31**, and **44** are considerably large ($\Delta\delta_{C_4-C_5}$ = 15–31 ppm), while those for 5-substituted triazoles such as **21**, **29**, and **32** are relatively small ($\Delta\delta_{C_4-C_5}$ = −2.5 to +13 ppm): this characteristic feature might be useful for determining the regiochemistry of 1*H*-1,2,3-triazole derivatives.

The 1,3-dipolar cycloadditions of phenyl azide have been studied extensively, and it is well-known that phenyl azide reacts fast with both electron-poor and with electron-rich dipolarophiles but slowly with intermediate, simple olefins.[22] The reactivity and regioselectivity of such 1,3-dipolar cycloadditions have been rationalized by FMO theory.[13,22,23] The comparison of the FMO of phenyl azide and 1-azidoadamantane (1) (Figure 1; the estimation of the FMO for phenyl azide is an elaborated one compared to that for 1)[23a,b] suggests that 1 may be as reactive as phenyl azide toward electron-poor dipolarophiles but less reactive toward electron-rich dipolarophiles and simple olefins because of its relatively higher LUMO energy. Some of these characteristic features were in fact observed experimentally as described above. As for regiochemistry of the 1,3-dipolar cycloadditions of 1, the steric bulkiness of the adamantyl group had a considerable effect. Because of the striking thermal stability of 1, longer heating of 1 without decomposition is possible, and therefore, a preparative disadvantage of the relatively mild reactivity of 1 can be compensated for by longer heating. Thus, it can be concluded that 1 is one of the synthetically useful 1,3-dipoles.

## Experimental Section[24]

### General Procedure for the 1,3-Dipolar Cycloadditions of

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**1-Azidoadamantane (1) with Dipolarophiles.** A mixture of 1-azidoadamantane (1, 1.00 mmol) and an appropriate dipolarophile (0.81–7.35 mmol) in toluene (2 mL) was stirred at 25–110 °C. After removal of the solvent, the residue was purified by recrystallization, or on a silica gel (Mallinckrodt, 100 mesh) column eluted with $CH_2Cl_2$–$CH_3OH$ or $CH_2Cl_2$–$CH_3CO_2C_2H_5$ (Tables I and II).

**Conversion of 1-(1-Adamantyl)-4-(hydroxymethyl)-1*H*-1,2,3-triazole (31) to 1-(1-Adamantyl)-4-(methoxycarbonyl)-1*H*-1,2,3-triazole (28).** A mixture of the triazole **31** (175 mg, 0.751 mmol), potassium permanganate (255 mg, 1.61 mmol), and sodium hydroxide (23 mg, 0.575 mmol) in water (3.5 mL) was stirred for 15 h at room temperature. The mixture was decolorized by addition of 5% aqueous sodium thiosulfate, and the precipitates were filtered and washed with 5% aqueous sodium hydroxide (2 mL). The combined filtrate and washings were acidified (20% aqueous hydrochloric acid). The resulting precipitates were filtered, washed with water, and dried to afford crude carboxylic acid (93 mg, 50.1%). Treatment of the acid with diazomethane (ca. threefold excess) in ether for 12 h at room temperature and removal of the solvent and excess diazomethane gave crude methyl ester which was purified by preparative TLC (silica gel, $CH_2Cl_2$–$CH_3OH$) to afford **28** (78 mg, 39.7% overall), identified by having the same IR and $^1H$ NMR spectra as those of the sample obtained from the cycloaddition.

**1-(1-Adamantyl)-5-(methoxycarbonyl)-1*H*-1,2,3-triazole (29) from 32.** A mixture of triazole **32** (80 mg, 0.34 mmol), potassium permanganate (148 mg, 0.94 mmol), Aliquat 336 (50 mg) in benzene (5 mL), and water (5 mL) was stirred vigorously for 12 h at room temperature and decolorized by addition of 5% aqueous thiosulfate. The resulting precipitates were filtered and washed with 5% hydrochloric acid and benzene. The organic layer of combined filtrate and washings was separated, and the water layer was extracted with benzene (5 × 5 mL). The combined organic layer and benzene extracts were extracted with 10% aqueous sodium hydroxide (5 × 5 mL). Acidification of the combined alkaline extracts with 20% hydrochloric acid gave crude acid product as colorless precipitates (50 mg, 58.9%) which on treatment with an excess of diazomethane in ether for 12 h afforded the **methyl ester 29** as colorless crystals after chromatography on a silica gel column ($CH_2Cl_2$); mp 137–138 °C. For analytical and spectral data, see Tables II and III.

**Lithium Aluminum Hydride Reduction of 1-(1-Adamantyl)-4-(ethoxycarbonyl)-1*H*-1,2,3-triazole (34) to 31.** A mixture of triazole **34** (50 mg, 0.18 mmol) and lithium aluminum hydride (100 mg, 2.64 mmol) in ether (10 mL) was heated under reflux for 2 h. The cooled mixture was treated with water, the organic layer was separated, and the water layer was extracted with ether (5 × 5 mL). The combined organic layer and extracts were dried ($Na_2SO_4$). Removal of the solvent gave an oily residue which on sublimation at 130–150 °C (0.2 mmHg) afforded the **(hydroxymethyl)triazole 31** as colorless crystals (40 mg, 94.2%). The IR and $^1H$ NMR spectra were superimposable on those of the specimen obtained from the cycloaddition of 1 with **30**.

**Oxidation of 4-(Ethoxycarbonyl)-1-(1-adamantyl)-$\Delta^2$-1,2,3-triazoline (16) to the Corresponding Triazole 34.** A mixture of the triazoline **16** (49 mg, 0.18 mmol) and potassium permanganate (100 mg, 0.64 mmol) in acetone (5 mL) was stirred for 3 days at room temperature. The mixture was decolorized by addition of ethanol (2 mL), and the resulting precipitates were removed by filtration. Removal of the solvent gave a solid residue which was purified on a silica gel column eluted with $CH_2Cl_2$–AcOEt to afford the **triazole 34** as colorless crystals after recrystallization from *n*-hexane (35 mg, 70.6%). The melting point and IR and $^1H$ NMR spectra were identical with those of the specimen obtained by the cycloaddition of 1 with **33**.

**4-(Acetoxymethyl)-1-(1-adamantyl)-1*H*-1,2,3-triazole (44).** This compound was prepared by acetylation of the 4-(hydroxymethyl)triazole **31** with acetic anhydride in pyridine. The usual workup afforded the acetate **44** in 76.3% yield as colorless crystals, mp 96–97 °C (*n*-hexane). For spectral and analytical data, see Tables II and III.

**Registry No.** **1**, 24886-73-5; **2**, 498-66-8; **3**, 121-46-0; **4**, 7350-72-3; **5**, 573-57-9; **6**, 76599-30-9; **7**, 76599-30-9; **8**, 76599-32-1; **9**, 76599-33-2; **10**, 76599-34-3; **11**, 3638-64-0; **12**, 20451-53-0; **15**, 140-88-5; **16**, 76599-35-4; **17**, 76599-49-0; **18**, 102-96-5; **21**, 76599-36-5; **22**, 76599-37-6; **23**, 536-74-3; **24**, 40430-66-8; **25**, 76599-38-7; **27**, 922-67-8; **28**, 76599-39-8; **29**, 76599-40-1; **30**, 107-19-7; **31**, 76599-41-2; **32**, 76599-42-3; **33**, 623-47-2; **34**, 76599-43-4; **36**, 762-42-5; **37**, 110-65-6; **38**, 501-65-5; **39**, 78-66-0; **40**, 76599-44-5; **41**, 76599-45-6; **42**, 76599-46-7; **43**, 76599-47-8; **44**, 76599-48-9.

# Structure of Anhydroacetylsalicylamide

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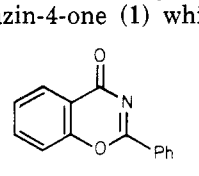
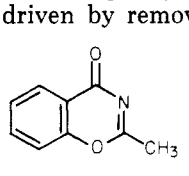
Anhydroacetylsalicylamide, previously reported[3] as 2-methyl-4*H*-1,3-benzoxazin-4-one (**2**), has been shown by chemical and spectroscopic analysis to be 2-[2-(2-hydroxybenzamido)propenyl]-4*H*-1,3-benzoxazin-4-one (**8**) or its simple tautomer **9**. The product of the reaction of this substance with ammonia has been shown to be 2-(2-hydroxyphenyl)-4-methyl-6-(2-hydroxybenzamido)pyrimidine (**4**).

In 1910 Titherley reported the acid-catalyzed dehydration of *O*- or *N*-benzoylsalicylamide to 2-phenyl-4*H*-1,3-benzoxazin-4-one (**1**) which is driven by removal of a




**1**




**2**

water-containing azeotrope.[2] In his hands other acylsalicylamides failed to give identifiable dehydration products under similar conditions. Forty-eight years later, Hanada reported that a modification of Titherley's conditions converts the acetylsalicylamides to a yellow substance, X (mp 217 °C), to which he assigned the structure 2-methyl-4*H*-1,3-benzoxazin-4-one (**2**).[3] This structural assignment has been accepted in a number of reports.[4] In this paper we demonstrate that anhydroacetylsalicylamide (X) is not **2** but has a more complex and interesting structure.

An examination of the UV spectra of anhydroacetylsalicylamide (X) and anhydrobenzoylsalicylamide reveals that the former has a more complex chromophore with a

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