

## Organic Azides. 2.\* Synthesis and Cycloaddition of Propargylic Azides

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The preparation of some primary propargylic azides and their reaction with dimethyl acetylenedicarboxylate (DMAD) is described. The tricyclic dimer of 3-azido-1-propyne was isolated.

Propargylic azides are interesting starting materials in organic synthesis since they contain a reactive azido group<sup>1</sup> and a carbon–carbon triple bond.<sup>2</sup> The simplest representative of this group, 3-azido-1-propyne (*1*), was first prepared from 3-bromo-1-propyne and tetramethylguanidinium azide (TMGA) in sulfolane.<sup>3</sup> Recently we reported on the UV photolysis of *1* in nitrogen matrices<sup>4</sup> and on the direct introduction of the azido group into 3-bromo-1-propyne in aqueous sodium azide solution under ultrasonic irradiation.<sup>5</sup>

3-Azido-1-propyne can also be prepared from iodoallene and TMGA in 82 % yield. This is formally a 1,3-substitution reaction on the propadiene system.

The acetylenic hydrogen-deuterium exchange occurs by treating *1* several times with potassium deuteriumoxide in heavy water, yielding 3-azido-[1-<sup>2</sup>H]-1-propyne (*2*) in 99 % purity.

On heating an ether solution of *1*, a flocky voluminous light red polymer is obtained. 5*H*,10*H*-Bis[1,2,3]triazolo[1,5-*a*:1',5'-*d*]pyrazine (*3*), the dimer of propargyl azide, can be extracted from the solid with ether in a Soxhlet extractor. A similar polymer with viscous consistency was prepared in refluxing chloroform. In the extraction of *3*, chloroform was found to be less selective than ether.

The chemical shift of the ring proton is often useful in determining the structure of isomeric disubstituted triazoles.<sup>6</sup> Compound *3* may be considered as an example of a triazole with 1,5-dialkyl substitution pattern. The chemical shift for the ring proton is  $\delta$  7.80 in acetone-*d*<sub>6</sub>.

The reaction of 1,4-dibromo-2-butyne with sodium azide in aqueous ethanol proceeds at a moderate rate at room temperature. The conversion is complete after 24 h and 1,4-diazido-2-butyne (*4*) can be isolated in 73 % yield. 1,6-Dibromo-2,4-hexadiyne reacts to 1,6-diazido-2,4-hexadiyne (*5*) in 56 % yield under equal conditions. The neat diazides *4* and *5* are extremely explosive. They can be stored at –25 °C for some weeks. Shock and heat should be avoided.

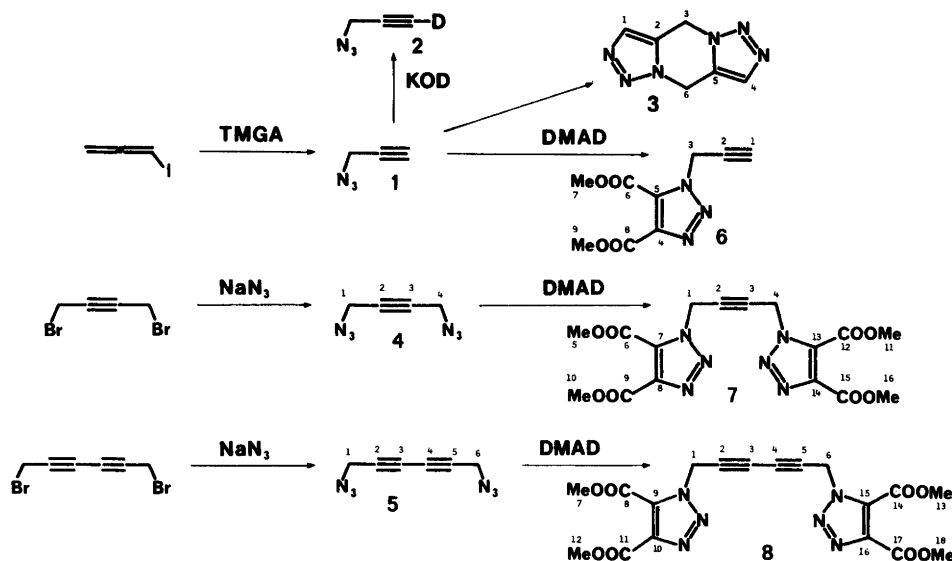
Since azides readily undergo cycloaddition reaction with dipolarophilic reagents,<sup>7</sup> I studied the reaction of the azides *1*, *4* and *5* with dimethyl acetylenedicarboxylate (DMAD). Since propargylazides contain triple bonds as potential dipolarophil in the same molecule, dimerisation and polymerisation are competing reactions at elevated temperatures. This is shown above in the case of *1*. Therefore all reactions with DMAD were carried out at 0 °C with long reaction times. The triazoles *6*, *7* and *8* crystallize from the ether solution after some days.

All structure formulas are given in formula scheme 1. The carbon atoms are numbered according to the <sup>13</sup>C NMR spectral data.

### EXPERIMENTAL

**Warning.** All azido compounds are known to be potentially explosive and appropriate caution should be applied!

\* Part 1. See Ref. 4.



**Scheme 1.** Synthesis and reactions of propargylic azides. Abbreviations: TMGA = Tetramethylguanidinium azide, DMAD = Dimethyl acetylenedicarboxylate. Carbon atoms are numbered according to the  $^{13}\text{C}$  NMR spectral data.

**Starting materials.** 1,4-Dibromo-2-butyne and 1,6-dibromo-2,4-hexadiyne were prepared from the corresponding dialcohols using a general synthetic method for 1-bromo-2-alkynes.<sup>8a</sup> 2,4-Hexadiyne-1,6-diol was prepared by oxidative coupling of 2-propyne-1-ol.<sup>8b</sup> Iodoallene<sup>8c</sup> and tetramethylguanidinium azide (TMGA)<sup>9</sup> were prepared according to the literature. Dimethyl acetylenedicarboxylate (DMAD) is commercially available.

**3-Azido-1-propyne (1):** Iodoallene (5.0 g, 30 mmol) is added to a solution of TMGA (14.3 g, 90 mmol) in sulfolane (80 ml) at 50 °C. After 1h the product is sucked into a trap cooled with liquid nitrogen, recondensed and dried by condensation through a U-shaped tube, which is slightly filled with phosphorus pentoxide. Yield 2.0 g (82 %). For analytical data see Refs. 3 and 5.

**3-Azido-[1- $^2\text{H}$ ]-1-propyne (2):** An Erlenmeyer flask containing 1 and 3 n potassium deuteriumoxide in heavy water is immersed 1–2 cm under the water surface in an ultrasonic cleaner (Bandelin Type Sonorex RK255, 500W, 35 kHz). During ultrasonic irradiation the temperature is hold between 0 and 10 °C. After 1h the product is sucked into a trap cooled with liquid nitrogen. The IR gas spectrum shows 77 % deuteration degree. Therefore the whole operation is repeated another three times with the partially

deuterated sample. The deuteration degree increased to over 99 %. IR (gas): 2922 (m, C-H), 2618, 2604 (s,  $\equiv\text{C}-\text{D}$ ), 2123 (vs,  $\text{N}_3$  as), 1256 (vs,  $\text{N}_3$  sy), 492 (vs,  $\equiv\text{C}-\text{D}$   $\delta$ )  $\text{cm}^{-1}$ .

**5*H*,10*H*-Bis[1,2,3]triazolo[1,5-*a*:1',5'-*d*]pyrazine (3):** A solution of 1 (2.4 g, 30 mmol) in ether (500 ml) is refluxed for 8 d. The flocky light red solid is filtered off and extracted with ether in a Soxhlet extractor for 10 d. 3 (0.4 g, 16 %) precipitates from the ether solution as a white flocky solid. Subl. 200–250 °C/13 Pa (0.1 Torr). Found: C 45.20; H 3.52; N 51.45. Calc. for  $\text{C}_6\text{H}_6\text{N}_6$ : C 44.44; H 3.72; N 51.82. IR (KBr): 3137 (m, =C-H), 1552 (s, C=C), 868, 831 (vs, C-H  $\delta$ )  $\text{cm}^{-1}$ .  $^1\text{H}$  NMR [200 MHz,  $(\text{CD}_3)_2\text{CO}$ ]:  $\delta$  7.80 (2 H, s, =CH-), 5.90 (4 H, s, -CH<sub>2</sub>-).  $^{13}\text{C}$  NMR [50.3 MHz,  $(\text{CD}_3)_2\text{CO}$ ]:  $\delta$  130.31 (C-1, C-4), 129.65 (C-2, C-5), 43.16 (C-3, C-6). UV [ $\text{CH}_3\text{CN}$  (log  $\epsilon$ ): 216 (3.83). MS [IP 70 eV;  $m/e$  (% rel. int.)]: 162 (100, M), 95 (56), 79 (10), 78 (13), 67 (20), 66 (14), 54 (51), 53 (89), 52 (80), 51 (19).

**1,4-Diazido-2-butyne (4):** a solution of sodium azide (6.2 g, 94 mmol), water (33 ml), 1,4-dibromo-2-butyne (2.5 ml, 23 mmol) and ethanol (100 ml) stands at room temperature for one day. Ethanol is sucked off and water (100 ml) is added. The reaction mixture is extracted with ether (4×100 ml). The ether solution is dried over calcium chloride and concentrated in a

water-pump vacuum. **4** (2.3 g, 73 %) remains as a yellowish liquid, b.p. 26 °C/13 Pa (0.1 Torr).  $n_D^{20}$  1.5055. IR (film): 2915 (m, C–H), 2100 (vs,  $N_3$ ), 1250 (vs,  $N_3$ )  $cm^{-1}$ .  $^1H$  NMR (200 MHz,  $CDCl_3$ ):  $\delta$  4.00 (4 H, s).  $^{13}C$  NMR (50.3 MHz,  $CDCl_3$ ):  $\delta$  78.81 (C-2, C-3), 39.24 (C-1, C-4). UV [ $CH_3CN$  (log  $\epsilon$ ): 221 (2.74) nm. MS [IP 70 eV;  $m/e$  (% rel. int.): 136 (11, M), 66 (6), 52 (23), 44 (7), 39 (20).

**1,6-Diazido-2,4-hexadiyne (5)**: a solution of sodium azide (4.1 g, 62 mmol), water (15 ml), 1,6-dibromo-2,4-hexadiyne (2.0 ml, 15.5 mmol) and ethanol (75 ml) stands at room temperature for one day. Ethanol is sucked off and water (100 ml) is added. The reaction mixture is extracted with ether (4×100 ml). The ether solution is dried over calcium chloride and concentrated in a water-pump vacuum. **5** (1.3 g, 56 %) remains as yellowish liquid, b.p. explodes at 95 °C/13 Pa (0.1 Torr).  $n_D^{20}$  1.5646. IR (film): 2900 (w, C–H), 2080 (vs,  $N_3$ ), 1250 (vs,  $N_3$ )  $cm^{-1}$ .  $^1H$  NMR (200 MHz,  $CDCl_3$ ):  $\delta$  4.04 (4 H, s).  $^{13}C$  NMR (50.3 MHz,  $CDCl_3$ ):  $\delta$  71.81 (C-2, C-5), 69.72 (C-3, C-4), 39.75 (C-1, C-6). UV [ $CH_3CN$  (log  $\epsilon$ ): 223 (3.86) nm. MS [IP 70 eV;  $m/e$  (% rel. int.): 160 (62, M), 132 (2), 118 (11), 90 (18), 89 (18), 88 (6), 77 (15), 76 (61), 75 (18), 74 (10), 64 (26), 63 (90), 62 (22), 61 (16), 51 (15), 50 (100), 49 (10).

**Dimethyl 1-(2-propynyl)-1H-1,2,3-triazole-4,5-dicarboxylate (6)**: A solution of **1** (0.34 g, 4.6 mmol) and DMAD (1.0 g, 7.0 mmol) in ether (5 ml) is stored in the refrigerator at 0 °C for 6 weeks. Crystallization can be initiated by occasional shaking of the flask. The residue is filtered off and recrystallized from acetone yielding **6** (0.69 g, 67 %) as colorless white needles, m.p. 88 °C. Found: C 48.56; H 4.00; N 19.22. Calc. for  $C_9H_9N_3O_4$ : C 48.43; H 4.06; N 18.82. IR (KBr): 3240 (s,  $\equiv C-H$ ), 2960 (m, C–H), 2120 (m,  $C\equiv C$ ), 1735 (vs,  $C=O$ ), 1565 (m,  $C=C$ ), 1230 (s, C–O), 1065 (s, C–O)  $cm^{-1}$ .  $^1H$  NMR (200 MHz,  $CDCl_3$ ):  $\delta$  5.44 (2 H, d,  $J$  2.58,  $-CH_2-$ ), 4.03 (3 H, s,  $OCH_3$ ), 3.98 (3 H, s,  $OCH_3$ ), 2.51 (1 H, t,  $J$  2.58,  $\equiv C-H$ ).  $^{13}C$  NMR (50.3 MHz,  $CDCl_3$ ):  $\delta$  160.24 (C-6), 158.39 (C-8), 140.44 (C-4), 129.65 (C-5), 75.42 (C-1), 74.75 (C-2), 53.52 (C-7), 52.74 (C-9), 40.44 (C-3). UV [ $CH_3CN$  (log  $\epsilon$ ): 219 (3.83) nm. MS [CI, Isobutane,  $m/e$  (% rel. int.): 223 (100, M), 194 (4), 163 (5).

**1,4-Bis[4,5-(dimethoxycarbonyl)-1H-1,2,3-triazol-1-yl]-2-butyne (7)**: A solution of **4** (0.25 g, 1.8 mmol) and DMAD (1.0 g, 7.0 mmol) in ether (5 ml) is stored in the refrigerator at 0 °C for 6 weeks. Recrystallization of the residue from chloroform/ether yields **7** (0.69 g, 90 %) as flocky yellowish crystals, m.p. 142 °C. Found: C 45.54; H 3.81; N 19.70. Calc. for  $C_{16}H_{16}N_6O_8$ : C 45.72;

H 3.84; N 19.99. IR (KBr): 2960 (m, C–H), 1740 (vs,  $C=O$ ), 1550 (m,  $C=C$ ), 1220 (vs, C–O), 1050 (s, C–O)  $cm^{-1}$ .  $^1H$  NMR (200 MHz,  $CDCl_3$ ):  $\delta$  5.45 (4 H, s,  $-CH_2-$ ), 3.99 (6 H, s,  $OCH_3$ ), 3.98 (6 H, s,  $OCH_3$ ).  $^{13}C$  NMR (50.3 MHz,  $CDCl_3$ ):  $\delta$  160.20 (C-6, C-12), 158.24 (C-9, C-15), 140.53 (C-8, C-14), 129.42 (C-7, C-13), 78.47 (C-2, C-3), 53.59 (C-5, C-11), 52.75 (C-10, C-16), 40.42 (C-1, C-4). UV [ $CH_3CN$  (log  $\epsilon$ ): 221 (4.01) nm. MS [IP 70 eV;  $m/e$  (% rel. int.): 420 (15, M), 361 (28), 302 (26), 301 (12), 236 (14), 208 (12), 207 (18), 204 (21), 177 (13), 176 (50), 168 (12), 154 (39), 149 (48), 148 (14), 144 (46), 140 (10), 126 (19), 124 (13), 119 (13), 118 (10), 91 (22), 82 (10), 78 (11), 68 (15), 67 (11), 66 (13), 65 (11), 64 (10), 63 (17), 59 (100), 53 (18), 52 (90), 51 (64), 45 (29), 44 (19), 43 (11), 42 (23).

**1,6-Bis[4,5-(dimethoxycarbonyl)-1H-1,2,3-triazol-1-yl]-2,4-hexadiyne (8)**: A solution of **5** (1.0 g, 6.1 mmol) and DMAD (2.6 g, 18.7 mmol) in ether (40 ml) is stored in the refrigerator for 6 weeks. Recrystallization of the residue from acetone yields **8** (2.4 g, 87 %) as yellowish brown cubes, m.p. 148 °C under decomposition. Found: C 48.64; H 3.86; N 19.11. Calc. for  $C_{18}H_{16}N_6O_8$ : C 48.65; H 3.62; N 18.91. IR (KBr): 2980 (m, C–H), 2940 (m, C–H), 2160 (vw,  $C\equiv C$ ), 2100 (w,  $C\equiv C$ ), 1725 (vs,  $C=O$ ), 1560 (s,  $C=C$ ), 1230 (vs, C–O), 1055 (vs, C–O)  $cm^{-1}$ .  $^1H$  NMR (200 MHz,  $CDCl_3$ ):  $\delta$  5.54 (4 H, s,  $-CH_2-$ ), 4.02 (6 H, s,  $OCH_3$ ), 3.97 (6 H, s,  $OCH_3$ ).  $^{13}C$  NMR (50.3 MHz,  $CDCl_3$ ):  $\delta$  160.13 (C-8, C-14), 158.23 (C-11, C-17), 140.58 (C-10, C-16), 129.29 (C-9, C-15), 71.20 (C-2, C-5), 70.23 (C-3, C-4), 53.61 (C-7, C-13), 52.78 (C-12, C-18), 40.90 (C-1, C-6). UV [ $CH_3CN$  (log  $\epsilon$ ): 219 (4.26) nm. MS [CI, Isobutane,  $m/e$  (% rel. int.): 444 (43, M), 200 (22), 186 (100), 154 (21).

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