

Natural Acetylenes. Part 53.¹ A Route to C₅, C₆, and C₇ *cis*- and *trans*-Alk-3-en-1-ynes *via* their Trimethylsilyl Derivatives²

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cis- and *trans*-1-Trimethylsilyl-pent-3-en-1-yne, -hex-3-en-1-yne, and -hept-3-en-1-yne have been prepared by fractional distillation of their *cis*-*trans*-mixtures and shown to provide a convenient route for the synthesis of the corresponding stereoisomeric terminal acetylenes.

PENT- and HEX-3-EN-1-YNES have been frequently required in the synthesis of natural acetylenes, *e.g.* *trans*-pentenyne (1a) for the C₁₇ alcohol (2) from dahlias³ and *cis*-hexenyne (1b) for the acetylenic feryl ketone (3) present in the broad bean.⁴ The need to synthesise labelled 14-*cis*- and 14-*trans*-dehydrocrepenynate (4) for biosynthetic experiments necessitated the preparation of *cis*- and *trans*-heptenyne (1c) and led to a convenient general route to the stereoisomeric C₅—C₇ alkenynes.

Alk-3-en-1-ynes can be synthesised in a number of ways, some leading predominantly to one of the stereoisomers.⁵ Most commonly the *cis*-*trans*-mixture is obtained either from alk-3-ynyl tosylates^{4,6,7} (this route has

been used in the present investigation) or from alk-2-ynyl ethers.⁸ The mixtures can be separated into stereoisomers by fractional distillation, as described for the C₅⁹ and C₇⁷ compounds, or by g.l.c. as described for the C₆ compound.⁴ Neither separation is particularly convenient because of the very close b.p.s of the stereoisomers, the losses incurred by the high volatility of the alkenynes, and their instability.

Silylation of the ethynyl group is known both to stabilise terminal acetylenes and to increase their b.p.s.¹⁰ The *cis*-*trans*-mixtures of the alkenynes (1a—c) were therefore silylated *via* their Grignard or lithio derivatives, most efficiently (*ca.* 80% yields) when *n*-butyl-lithium

¹ Part 52, I. W. Farrell, V. Thaller, and J. L. Turner, *J.C.S. Perkin 1*, 1977, 1886.

² A more detailed account of part of the work described in this paper is in the D.Phil. Thesis of I. W. Farrell, Oxford, 1977.

³ C. Chin, M. C. Cutler, Sir Ewart R. H. Jones, J. Lee, S. Safe, and V. Thaller, *J. Chem. Soc. (C)*, 1970, 314.

⁴ F. C. Fawcett, D. M. Spencer, R. L. Wain, A. G. Fallis, Sir Ewart R. H. Jones, M. Le Quan, C. B. Page, V. Thaller, D. C. Shubbrook, and P. M. Whitham, *J. Chem. Soc. (C)*, 1968, 2455.

⁵ *Cf.* E. J. Corey and R. A. Ruden, *Tetrahedron Letters*, 1973, 1495.

⁶ G. Eglinton and M. C. Whiting, *J. Chem. Soc.*, 1950, 3650.

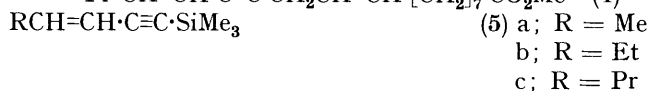
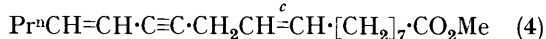
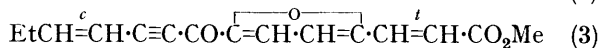
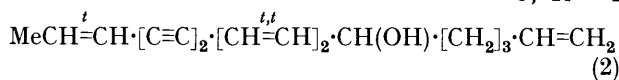
⁷ A. Butenandt and E. Hecker, *Angew. Chem.*, 1961, **73**, 349.

⁸ L. Brandsma, 'Preparative Acetylenic Chemistry,' Elsevier, Amsterdam, 1971, p. 124.

⁹ J. L. H. Allan and M. C. Whiting, *J. Chem. Soc.*, 1953, 3314.

¹⁰ *Cf.* R. Eastmond, T. R. Johnson, and D. R. M. Walton, *Tetrahedron*, 1972, **28**, 4601.

was added to the mixture of trimethylsilyl chloride and the *cis-trans*-alkenyne (cf. silylation of benzenes¹¹). The resulting trimethylsilyl derivatives (5a—c) were easy



to handle and the b.p.s of the stereoisomers differed sufficiently in each case (by *ca.* 6 °C) to make their separation by fractional distillation convenient (a spinning band column was used). The *cis*- and *trans*-isomer fractions of (5a—c) were characterised and their stereochemical purity ($\geq 94\%$) was determined by g.l.c. The *cis*- and *trans*-alkenyne (1a—c) could be regenerated as ethereal solutions by cleaving the carbon-silicon bond with silver nitrate¹² or fluoride ion,⁵ the cleavage proceeding in 85—90% yields. For example, by using the fluoride ion cleavage, an ethereal solution of the *cis*- and *trans*-hexenyne (1b) was obtained from the *cis-trans*-alkenyne mixture in 60% overall yield.

EXPERIMENTAL

For spectral techniques see Part 41.¹³

Spinning band distillations were carried out in a Nester-Faust Annular Still (NFA-200) operating at 7 000 rev. min⁻¹. For g.l.c. a Pye 104 series 24 instrument with 10% polyethylene glycol succinate on Embacel (60—100 mesh) packed in a 150 × 0.3 cm column (N₂ flow 45 ml min⁻¹) was used.

Tetrahydrofuran (THF) was purified by refluxing with Na wire and benzophenone prior to distillation and was stored over Linde 4 Å molecular sieve. Solutions of BuⁿLi in hexane were standardised by the double titration method using benzyl chloride.

(a) *Silylation via the Li Salts*.—*cis*- and *trans*-1-Trimethylsilylpent-3-en-1-yne (5a). *cis-trans*-Pent-3-en-1-yne (1a)⁶ (4.5 g, 68 mmol; 55% *cis*-isomer) and Me₃SiCl (7.49 g, 69 mmol) in anhydrous THF (50 ml) were cooled (Me₂CO—solid CO₂) under N₂. BuⁿLi in hexane (42.5 ml, 68 mmol) was added dropwise to the stirred solution (the red-brown colour of the acetylide ion was briefly seen). After the addition was completed a fine white precipitate slowly appeared. The stirred mixture was allowed to warm to 20 °C over 12 h. It was then poured into an excess of dil. HCl and extracted with Et₂O. The extract was dried (MgSO₄) and concentrated under N₂ at 760 mmHg. The residue was fractionally distilled and gave *cis-trans*-1-trimethylsilylpent-3-en-1-yne (8.4 g, 89%; 56% *cis*-isomer), b.p. 68—75° at 50 mmHg. The mixture of isomers (12.35 g) was separated by fractional

distillation on a spinning-band column using *p*-cymene as chaser and gave *cis*-1-trimethylsilylpent-3-en-1-yne [*cis*-(5a)] (5.38 g, 43.5%; contaminated with 2.5% *trans*-isomer), b.p. 62° at 46 mmHg (Found: C, 70.1; H, 10.4. C₈H₁₄Si requires C, 69.5; H, 10.1%), *n*_D¹⁹ 1.4575, *t*_R (48.5 °C) 3.0 min, *v*_{max}(CCl₄) 3 030, 2 150, and 2 120 cm⁻¹, *v*_{max}(CS₂) 1 250, 840br, and 720 cm⁻¹, *τ*(CCl₄) 9.98 (9 H, s, SiMe₃), 8.3 (3 H, dd, *J* 7 and 1.5 Hz, CH₃·CH=CH), 4.8 (1 H, dq, *J* 11 and 1.5 Hz, CH₃·CH=CH), and 4.2 (1 H, dq, *J* 11 and 6.5 Hz, CH₃·CH=CH), *m/e* 138 (*M*⁺, 50%), 123 (100), 107 (8), 95 (27), 81 (10), 69 (22), and 67 (22); and the *trans*-isomer [*trans*-(5a)] (3.9 g, 29%; contaminated with 6% *cis*-isomer), b.p. 68° at 46 mmHg (Found: C, 69.5; H, 10.1. C₈H₁₄Si requires C, 69.5; H, 10.1%), *n*_D¹⁹ 1.4625, *t*_R (48 °C) 4.4 min, *v*_{max}(CCl₄) 3 030, 2 170, 2 130, and 955 cm⁻¹, *v*_{max}(CS₂) 840br cm⁻¹, *τ*(CCl₄) 9.9 (9 H, s, SiMe₃), 8.3 (3 H, dd, *J* 7 and 2 Hz, CH₃·CH=CH), 4.7 (1 H, dq, *J* 16 and 2 Hz, CH₃·CH=CH), and 4.0 (1 H, dq, *J* 16 and 6.5 Hz, CH₃·CH=CH), *m/e* 138 (*M*⁺, 25%), 123 (100), 109 (7), 107 (6), 97 (7), 95 (12), 83 (10), 6 (15), and 59 (15). An intermediate fraction (0.9 g, 7.3%) had a *cis* : *trans* ratio of *ca.* 2 : 1.

cis- and *trans*-1-Trimethylsilylhex-3-en-1-yne (5b). Analogously, *cis-trans*-hex-3-en-1-yne (1b)⁴ (7.6 g, 95 mmol; 55% *cis*-isomer), Me₃SiCl (10.9 g, 100 mmol), and BuⁿLi in hexane (59 ml, 95 mmol) in THF (100 ml) gave, after distillation, *cis-trans*-1-Me₃Si-hex-3-en-1-yne (5b) (11.4 g, 79%; 53% *cis*-isomer), b.p. 58—72° at 12 mmHg. Separation of the mixture (23 g) gave *cis*-1-trimethylsilylhex-3-en-1-yne [*cis*-(5b)] (10.7 g, 46.5%; contaminated with <0.1% *trans*-isomer), b.p. 72° at 56 mmHg (Found: C, 71.0; H, 10.8. C₉H₁₆Si requires C, 71.0; H, 10.7%), *n*_D²⁰ 1.4558, *t*_R (52 °C) 3.5 min, *v*_{max}(CCl₄) 3 020, 2 160, and 2 140 cm⁻¹, *v*_{max}(CS₂) 1 250, 840, and 740 cm⁻¹, *τ*(CCl₄) 9.98 (9 H, s, SiMe₃), 9.15 (3 H, t, *J* 7 Hz, CH₃·CH₂), 7.9 (2 H, m, CH₃·CH₂·CH=), 4.8 (1 H, dt, *J* 10 and 1.5 Hz, CH₂·CH=CH·C≡), and 4.3 (1 H, dt, *J* 10 and 7 Hz, CH₂·CH=CH·C≡), *m/e* 152 (*M*⁺, 20%), 137 (100), 123 (6), 109 (11), 97 (7), 95 (6), 73 (10), and 50 (13); and the *trans*-isomer [*trans*-(5b)] (8.23 g, 36%; contaminated with 2% *cis*-isomer), b.p. 84—86° at 56 mmHg (Found: C, 71.2; H, 10.8. C₉H₁₆Si requires C, 71.0; H, 10.7%), *n*_D²⁰ 1.4652, *t*_R (52 °C) 7.5 min, *v*_{max}(CCl₄) 3 020, 2 180, 2 140, and 950 cm⁻¹, *v*_{max}(CS₂) 1 250 and 840 cm⁻¹, *τ*(CCl₄) 9.98 (9 H, s, SiMe₃), 9.1 (3 H, t, *J* 7 Hz, CH₃·CH₂), 8.0 (2 H, m, CH₃·CH₂·CH=), 4.75 (1 H, dt, *J* 16 and 1.5 Hz, CH₂·CH=CH·C≡), and 4.0 (1 H, dt, *J* 16 and 7 Hz, CH₂·CH=CH·C≡), *m/e* 152 (*M*⁺, 20%), 137 (100), 122 (4), 109 (7), 107 (6), 97 (4), 83 (14), 81 (5), 73 (6), 69 (7), and 59 (14). An intermediate fraction, b.p. 72—84° at 56 mmHg (0.77 g, 3.3%), had a *cis* : *trans* ratio of *ca.* 2 : 1.

cis- and *trans*-1-Trimethylsilylhept-3-en-1-yne (5c). *cis-trans*-Hept-3-en-1-yne (1c)⁷ (8.7 g, 92.5 mmol, 55% *cis*-isomer), Me₃SiCl (12.2 g, 112 mmol), and BuⁿLi in hexane (55 ml, 93.5 mmol) in THF (90 ml) gave on distillation *cis-trans*-1-Me₃Si-hept-3-en-1-yne (5c) (11.8 g, 77%; 57% *cis*-isomer), b.p. 68—77° at 12 mmHg. Separation of the mixture (26 g) using tetrahydronaphthalene as chaser, gave *cis*-1-trimethylsilylhept-3-en-1-yne [*cis*-(5c)] (12.0 g, 46%; contaminated with <0.1% *trans*-isomer), b.p. 92—94° at 42 mmHg (Found: C, 71.6; H, 11.1. C₁₀H₁₈Si requires C, 72.1; H, 10.9%), *n*_D²⁰ 1.4608, *t*_R (53 °C) 6.2 min, *v*_{max}(CCl₄) 3 010, 2 150, and 2 115 cm⁻¹, *v*_{max}(CS₂) 1 250, 840, and 735 cm⁻¹, *τ*(CCl₄) 9.98 (9 H, s, SiMe₃), 9.2 (3 H, t, *J* 7 Hz, CH₃·

¹¹ R. Naylor, *Tetrahedron Letters*, 1975, 435.

¹² H. M. Schmidt and J. F. Arens, *Rec. Trav. chim.*, 1967, **86**, 1138.

¹³ I. W. Farrell, J. W. Keeping, M. G. Pellatt, and V. Thaller, *J.C.S. Perkin I*, 1973, 2642.

CH₂), 8.8 (2 H, m, CH₃·CH₂·CH₂), 7.9 (2 H, m, CH₂·CH₂·CH=), 4.8 (1 H, dt, *J* 11 and 1 Hz, CH₂·CH=CH·C≡), and 4.3 (1 H, dt, *J* 11 and 7 Hz, CH₂·CH=CH·C≡), *m/e* 166 (*M*⁺, 16%), 151 (100), 137 (2), 124 (4), 122 (2), 109 (12), 107 (6), 97 (4), 83 (11), 73 (15), and 59 (20); and the *trans*-isomer [*trans*-(5c)] (9.24 g, 35.5%; contaminated with 1% *cis*-isomer), b.p. 101° at 42 mmHg (Found: C, 72.5; H, 11.1. C₁₀H₁₈Si requires C, 72.1; H, 10.9%), *n*_D²⁰ 1.4736, *t*_R (53 °C) 11.7 min, *v*_{max}(CCl₄) 3 010, 2 170, 2 135, and 955 cm⁻¹, *v*_{max}(CS₂) 1 250 and 840 cm⁻¹, *τ*(CCl₄) 9.98 (9 H, s, SiMe₃), 9.2 (3 H, t, *J* 7 Hz, CH₃·CH₂), 8.7 (2 H, m, CH₃·CH₂·CH₂), 8.0 (2 H, m, CH₂·CH₂·CH=), 4.8 (1 H, dt, *J* 16 and 1 Hz, CH₂·CH=CH·C≡), and 4.0 (1 H, dt, *J* 16 and 7 Hz, CH₂·CH=CH·C≡), *m/e* 166 (*M*⁺, 20%), 153 (7), 151 (100), 122 (8), 109 (12), 107 (8), 96 (5), 94 (5), 83 (11), 73 (10), and 59 (13). An intermediate fraction, b.p. 94–101° at 42 mmHg (0.92 g, 3.5%), had a *cis* : *trans* ratio of *ca.* 1 : 2.

(b) *Silylation via the Grignard Reagents*.—*cis*-*trans*-1-Trimethylsilyl-pent-3-en-1-yne (5a). *cis*-*trans*-Pent-3-en-1-yne (1a) (9.2 g, 140 mmol) in THF (20 ml) was added at 0 °C to a stirred solution of EtMgBr, [from EtBr (18.6 g, 172 mmol) and Mg turnings (4.3 g, 172 mmol) in THF (100 ml)]. After 1 h, Me₃SiCl (18.6 g, 172 mmol) in THF (20 ml) was added to the mixture at 0 °C and stirring was continued for 12 h at 20 °C. The mixture was poured into an excess of dil. HCl-ice and extracted with Et₂O. The extract was washed with brine and dried (MgSO₄ and then mol. sieve). Concentration was carried out under N₂ on a water-bath (< 70 °C) using a 30 cm unlagged Dufton column. Fractional distillation of the residue gave *cis*-*trans*-1-trimethylsilyl-

pent-3-en-1-yne (12.35 g, 64%; *ca.* 5 : 4 *cis* : *trans*), b.p. 68–75° at 50 mmHg.

cis-*trans*-1-Trimethylsilylhex-3-en-1-yne (5b). Similarly, *cis*-*trans*-hex-3-en-1-yne (1b) (8.7 g, 109 mmol) in THF (10 ml), EtBr (9.45 g, 85 mmol), and Mg turnings (2.1 g, 85 mmol) in THF (50 ml), and Me₃SiCl (9.45 g, 85 mmol) in THF (10 ml) gave *cis*-*trans*-1-trimethylsilylhex-3-en-1-yne (8.3 g, 50.5%; *ca.* 1 : 1 *cis* : *trans*), b.p. 86–96° at 55 mmHg.

cis-*trans*-1-Trimethylsilylhept-3-en-1-yne (5c). *cis*-*trans*-Hept-3-en-1-yne (1c) (17.7 g, 168 mmol) in THF (50 ml), EtBr (22 g, 240 mmol) and Mg-turnings (4.9 g, 240 mmol) in THF (200 ml), and Me₃SiCl (31 g, 277 mmol) gave *cis*-*trans*-1-trimethylsilylhept-3-en-1-yne (24 g, 77%; *ca.* 5 : 4 *cis* : *trans*).

trans-Hex-3-en-1-yne [*trans*-(1b)].—*trans*-1-Trimethylsilylhex-3-en-1-yne [*trans*-(5b)] (99 mg, 0.72 mmol; contaminated with < 2% *cis*-isomer) in HCONMe₂ (1 ml) was added to a stirred suspension of KF·2H₂O (500 mg, 5.3 mmol) in HCONMe₂ (4 ml). After 30 min, g.l.c. showed > 90% conversion into *trans*-hex-3-en-1-yne (< 2% *cis*-isomer); no other product was detected. The mixture was poured into dil. HCl (10 ml) and extracted with Et₂O. The extract was washed successively with dil. HCl and brine, and dried (MgSO₄). Filtration gave an Et₂O solution of *trans*-hex-3-en-1-yne.

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