Base Catalysed Rearrangements involving Ylide Intermediates. Part 5.[1] Thermal Rearrangements of 3-Dimethylaminohex-5-en-1-ynes

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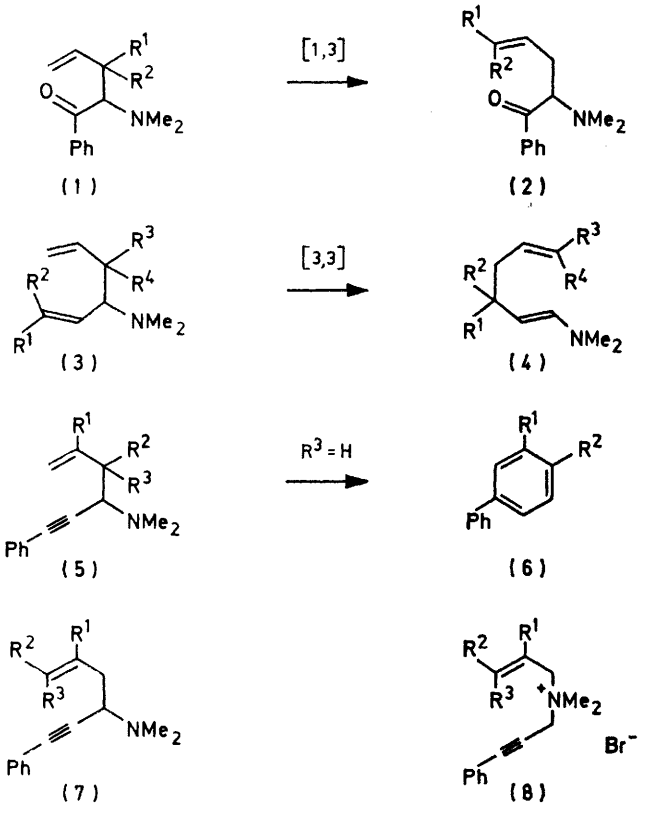
Thermal rearrangements of 3-dimethylaminohex-5-en-1-ynes (5) yield biphenyls (6). The mechanism of the transformation (5) ⟶ (6) involves a sequence of (i) a [3,3] sigmatropic rearrangement, (ii) a [1,3] hydrogen shift, (iii) an electrocyclic reaction, and (iv) elimination of dimethylamine (Scheme 2).

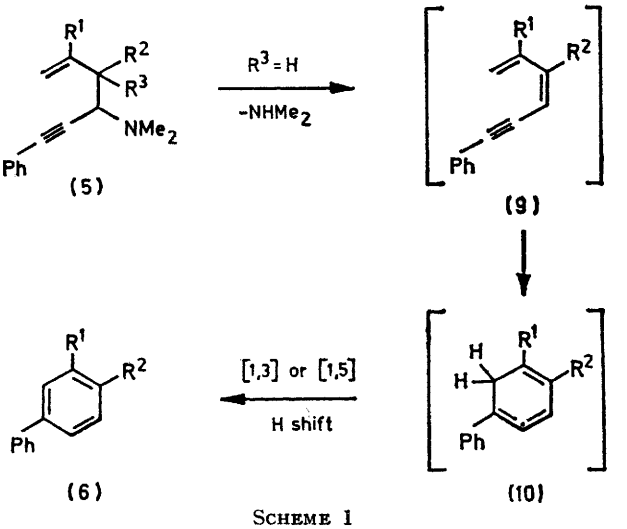
In Part 3,[2] the thermal [1,3] sigmatropic rearrangement of α-allyl-α-dimethylamino-ketones (1) leading to isomers (2) was described. In Part 4,[1] the thermal [3,3] sigmatropic rearrangement of 3-dimethylaminohexa-1,5-dienes



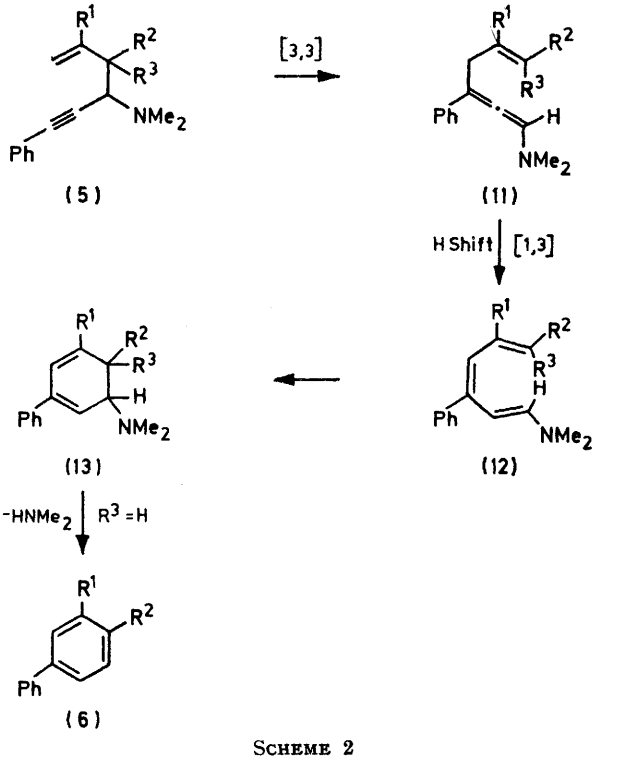
(3) giving the enamines (4) was reported. We now describe [3] the thermal transformations of the 3-dimethylaminohex-5-en-1-ynes (5) which take a completely different course, yielding the biphenyls (6). The isomers (7), however, remain unchanged under similar thermal conditions.

The amines (5) were prepared by base catalysed [3,2] sigmatropic rearrangement of the allyl- (3-phenylprop-2-ynyl)ammonium salts (8);[3,4] the amines (7) were obtained as the minor products in these reactions and are formed by a Stevens [1,2] rearrangement (see Part 1).[3,4] When the amine (5a) (see Table) was heated in refluxing xylene for 1 h, the only isolated product was *p*-terphenyl (6a) (70%). Similarly the amines (5b—e) were transformed into the biphenyls (6b—e) after heating at 140 or 200° for periods of up to 7 days (see Table). The isomeric amines (7a and f) were recovered unchanged after heating under similar conditions.

Two mechanisms (Schemes 1 and 2) were considered

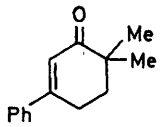


SCHEME 1



SCHEME 2

to account for the transformations (5) ⟶ (6). According to Scheme 1, elimination of dimethylamine could give a conjugated dienyne (9) which could undergo an *electrocyclic* reaction [5,6] leading to the transient cyclic



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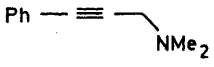

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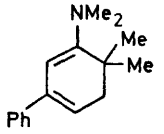


(16)

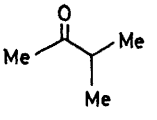
allenic intermediate (10). The cyclic allene (10) could yield the biphenyl (6) by a [1,3] or a [1,5] hydrogen shift.

According to Scheme 2, a [3,3] sigmatropic rearrangement [7] analogous to the rearrangement (3) ⟶ (4) [2] could give the allene-amine (11), which by a [1,3] hydrogen shift could lead to the hexatriene (12). An electrocyclic reaction [5,8] (12) ⟶ (13) followed by elimination of dimethylamine [8] could give the biphenyl (6).

Of the two mechanisms (Schemes 1 and 2), Scheme 2 seems more attractive since each stage has many analogies. In contrast, Scheme 1 involves cyclic allene intermediates which are rare.[9] Evidence in support of Scheme 2 was obtained by heating the amine (5f). This compound (5f) cannot eliminate dimethylamine as required by the first stage of Scheme 1 or the last stage of Scheme 2. When the amine (5f) was heated (140°; 3 days) and the resultant mixture was treated with dilute acid, the products were the ketone (14) (30%), the amine (13f) (12%), the cleavage product (15) (12%), and 4-methylbiphenyl (1%). The ketone is presumably formed by hydrolysis of the enamine (16) which is produced by a thermal [1,5] hydrogen shift in the amine (13f). In agreement with this proposal, thermolysis of the amine (5f) at 200° for 6 h gave only the ketone (14): the amine (13f) was not detected.

The constitution of the ketone (14) follows from spectral data (see Experimental section) and also from synthesis [10] (Scheme 3). Refluxing a mixture of β-chloropropiophenone (17) and 3-methylbutan-2-one (18) with one equivalent of sodium 1,1-dimethylpropoxide gave the ketone (14) in low yield. The structure of the amine (13f) was established solely on spectral data.

The mechanism for the transformation (5) ⟶ (6) (Scheme 2) involves a sequence of pericyclic reactions similar to those already advanced to account for the thermal rearrangements of aryl prop-2-ynyl ethers to chromens,[11] prop-2-ynyl vinyl sulphides to thiapyrans,[12] prop-2-ynylnaphthylamines to benzoquinolines,[13] and propargylic pseudoureas to pyridones.[14]



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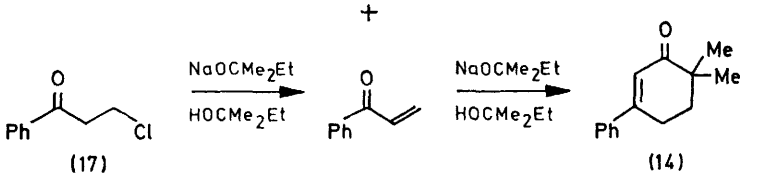
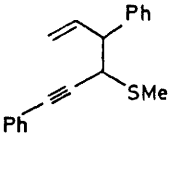


(17) (14)

SCHEME 3

It is interesting to note that the sulphide (19), prepared by base catalysed [3,2] sigmatropic rearrangement of the sulphonium salt (20), also underwent thermal rearrangement to *p*-terphenyl (6a) (30%) after heating at 200° for 4 h. The slower rate of reaction (19) ⟶ (6a) compared with the corresponding reaction (5a) ⟶ (6a) is consistent with recent results showing the stabilising effect of amino-substituents upon transition states associated with sigmatropic rearrangements.[2,15]



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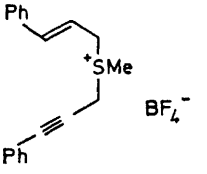

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Thermal rearrangements of 3-dimethylaminohex-5-en-1-ynes (5) to biphenyls (6)

Compd.	R^1	R^2	R^3	Temp. (°C)	Time	Yield of (6) (%)
(a)	H	Ph	H	140	1 h	70
(b)	H	Me	H	200	3 days	60 *
(c)	H	H	H	140	7 days	58 †
(d)	Ph	H	H	140	3 days	95
(e)	Me	H	H	200	12 h	95
(f)	H	Me	Me	140	3 days	0 ‡

* 12% starting material (5b) recovered. † 60% starting material (5c) recovered. ‡ Formation of (6) is impossible. Actual products are (13f) (12%), (14) (30%), and (15) (12%).

EXPERIMENTAL

The general directions were given in Part 1.[4]

Thermal Rearrangements of 3-Dimethylamino-1-phenylhex-5-en-1-ynes (5). *Formation of Biphenyls* (6).—The amines [4] (5) were either dissolved in dry xylene and heated under reflux, or heated at 200° in a sealed evacuated tube. After cooling, the product was separated into neutral and basic fractions using 5N-hydrochloric acid, 5N-sodium hydroxide,

and ether extraction. The neutral fraction was purified by crystallisation or preparative t.l.c. giving the biphenyls (6), which were identified by comparison with authentic samples. The basic fraction contained any unchanged starting material (5). The yields of products (6), based on reacted (5), and the thermolysis conditions are given in the Table.

Thermal Rearrangement of 4,4-*Dimethyl*-3-*dimethylamino*-1-*phenylhex*-5-*en*-1-*yne* (5f). *Formation of* 6,6-*Dimethyl*-3-*phenylcyclohexa*-2,4-*dienyl*-NN-*dimethylamine* (13f), 6,6-*Dimethyl*-3-*phenylcyclohex*-2-*enone* (14), 3-*Phenylprop*-2-*ynyl*-NN-*dimethylamine* (15), *and* 4-*Methylbiphenyl* (6b).—A solution of the amine (5f) (2.0 g) in dry xylene (25 ml) was refluxed for 3 days, evaporated, and the resultant oil was dissolved in ether (50 ml). The solution was extracted with 2N-hydrochloric acid, washed with water, dried, and evaporated giving a neutral fraction (0.63 g). The acidic extracts were neutralised with 5N-sodium hydroxide and extracted with ether. The ethereal extracts were dried and evaporated giving a basic fraction (1.25 g). The neutral and basic fractions were separated into four components by preparative t.l.c. Fraction (i) was 4-methylbiphenyl (6b) (60 mg), m.p. 47°. (lit.,[16] 47.5°). Fraction (ii) was 6,6-*dimethyl*-3-*phenylcyclohex*-2-*enone* (14), m.p. 52—54° (0.58 g, 30%), *m/e* 144 ($M - C_4H_8$) and 116 (144 − CO), *m** 103.6 (200 ⟶ 144) and 93.4 (144 ⟶ 116) (Found: M^+, 200. $C_{14}H_{16}O$ requires M, 200); $\nu_{max.}$ 1 645, 1 140, and 885 cm^{-1}; τ 2.4—2.8 (m, 5 aromatic H), AX_2Y_2 system, τ_A 3.68, τ_X 7.24, τ_Y 8.06 [J_{AX} 2, J_{XY} 6 Hz, $CH_A{=}C{-}C(H_X)_2{-}C(H_Y)_2{-}$], and 8.86 (s, CMe_2). The ketone (14) was characterised as its 2,4-*dinitrophenylhydrazone*, from methanol, m.p. 201—202° (Found: C, 63.5; H, 5.6; N, 14.6. $C_{20}H_{20}N_4O_4$ requires C, 63.2; H, 5.3; N, 14.7%).

Fraction (iii) was 6,6-*dimethyl*-3-*phenylcyclohexa*-2,4-*dienyl*-NN-*dimethylamine* (13f) (0.23 g, 12%), *m/e* 212, 183, 182 (M − $HNMe_2$), 168, and 167 (Found: M^+, 227. $C_{16}H_{21}N$ requires M, 227); τ 2.4—2.7 (m, 5 aromatic H), ABCX system, τ_A 4.25, τ_B 3.82, τ_C 4.00, τ_X 6.91 (J_{AB} 10, J_{BC} 1, J_{CX} 5 Hz, $CH_A{=}CH_B{-}C{=}CH_C{-}CH_XNMe_2$), 7.66 (s, NMe_2), 8.82 (s), and 8.93 (s, $>CMe_2$). The amine (13f) was characterised as its *picrate*, yellow prisms from ethanol, m.p. 112—114° (Found: C, 57.7; H, 5.6; N, 12.4. $C_{22}H_{24}N_4O_7$ requires C, 57.9; H, 5.3; N, 12.3%). Fraction (iv) was 3-phenylprop-2-ynyl-*NN*-dimethylamine [4] (15) (0.15 g, 12%).

6,6-*Dimethyl*-3-*phenylcyclohex*-2-*enone* (14).—A mixture of 3-methylbutan-2-one (18) (8.6 g) and sodium 1,1-dimethylpropoxide [prepared from sodium hydride (2.4 g) and 1,1-dimethylpropanol (8.8 g)] in dry benzene (100 ml) was treated with a solution of β-chloropropiophenone (17) (16.6 g) in dry benzene (100 ml). The solution was refluxed for 1 h, cooled, poured into water, and extracted with ether. The ethereal extracts were dried and evaporated giving a liquid which was distilled, collecting the fraction (1.0 g), b.p. 160° at 2 mmHg. This fraction was purified by preparative t.l.c. giving 6,6-*dimethyl*-3-*phenylcyclohex*-2-*enone* (14) (0.03 g, 1.5%) as plates, m.p. 52—54°, identical to the sample obtained previously.

Cinnamyl 3-*Phenylprop*-2-*ynyl Sulphide*.—A mixture of cinnamyl thiol (15.0 g), sodium hydride (2.4 g), and ethanol (50 ml) was stirred for 5 min and treated with a solution of 3-phenylprop-2-ynyl bromide (20.0 g) in ethanol. After stirring for 12 h at room temperature, the solution was poured into water and extracted with ether. The ethereal extracts were dried and evaporated giving *cinnamyl* 3-*phenylprop*-2-*ynyl sulphide* (25 g, 94%) (Found: M^+, 264. $C_{18}H_{16}S$ requires M, 264); τ 2.5—2.9 (m, 10 aromatic H), ABX_2 system, τ_A 3.46, τ_B 3.87, τ_X 6.56 [J_{AB} 16, J_{BX} 7 Hz, $CH_A{=}CH_B{-}C(H_X)_2{-}S$], and 6.60 (s, $CH_2{-}S$).

Cinnamylmethyl-(3-*phenylprop*-2-*ynyl*)*sulphonium Tetrafluoroborate* (20).—A solution of methyl iodide (3.0 g) in dichloromethane (10 ml) was added dropwise to a stirred mixture of cinnamyl 3-phenylprop-2-ynyl sulphide (5.0 g), silver tetrafluoroborate (4.0 g), and dichloromethane (25 ml). After 4 h at room temperature, the solution was filtered and the solid residue was washed several times with dichloromethane. The filtrate and washings were evaporated giving *cinnamylmethyl*-(3-*phenylprop*-2-*ynyl*)*sulphonium tetrafluoroborate* (20) as a hygroscopic oil; τ (CF_3CO_2H) 2.3—3.0 (m, 10 aromatic H), ABX_2 system, τ_A 2.8—3.0, τ_B 3.7, τ_X 5.68 [J_{AB} *ca.* 16, J_{BX} 7 Hz, $CH_A{=}CH_B{-}C(H_X)_2$], 5.55 (s, $CH_2{-}S^+$), and 6.97 (s, SMe).

Base Catalysed Rearrangement of Cinnamylmethyl-(3-*phenylprop*-2-*ynyl*)*sulphonium Tetrafluoroborate* (20). *Formation of* 1,4-*Diphenyl*-3-*methylthiohex*-5-*en*-1-*yne* (19).—The sulphonium salt (20) 6.0 g) was treated with a solution prepared from sodium hydride (0.48 g), methanol (1 ml), and dimethyl sulphoxide (20 ml). The mixture was stirred overnight, poured into water, and extracted with ether. The ethereal extracts were washed with water, dried, and evaporated giving a pale yellow oil which was purified by preparative t.l.c. giving 1,4-*diphenyl*-3-*methylthiohex*-5-*en*-1-*yne* (19) (2.0 g); τ 2.4—2.8 (m, 10 aromatic H), ABMXY system, τ_A 4.78, τ_B 4.82, τ_M 4.70, τ_X 6.01, τ_Y 6.32 (J_{AB} 1, J_{BM} 17, J_{MX} 8, J_{XY} 7 Hz, $CH_AH_B{=}CH_M{-}CH_XCH_Y{-}SMe$), and 7.78 (s, SMe).

Thermal Rearrangement of 1,4-*Diphenyl*-3-*methylthiohex*-5-*en*-1-*yne* (19). *Formation of* p-*Terphenyl* (6a).—The sulphide (19) (0.4 g) was heated in a sealed evacuated tube at 200° for 4 h. The resultant black solid was purified by preparative t.l.c. giving *p*-terphenyl (0.1 g, 30%), m.p. 210—212° (lit.,[17] 212°).

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