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Studies in Bromoacetylenic Oxy-Cope Rearrangement: Synthesis of Functionalised Medium-Size, Bicyclic and Angularly Fused Tricyclic Compounds

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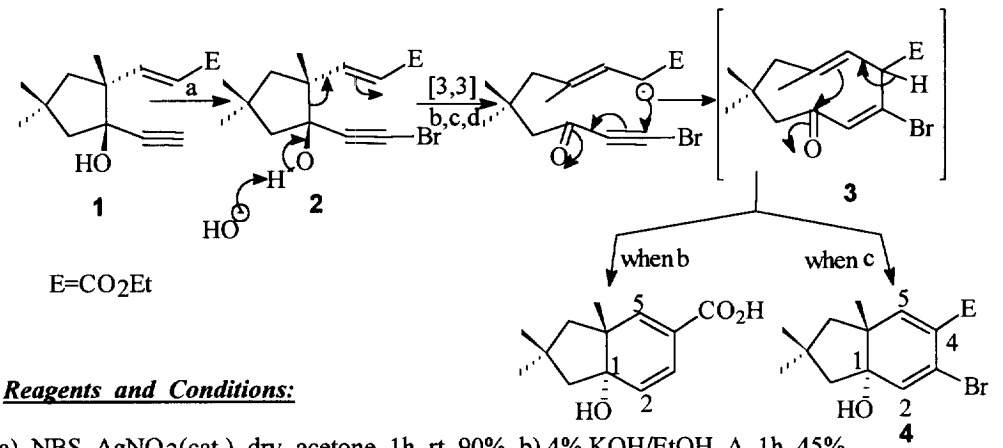
Abstract: Functionalised title compounds **4, 7, 11, 12** and **16** were synthesised from bromoethynyl derivatives of cycloalkanes **2, 6,** Wieland-Meisher ketone **10** and spiro[5.5] ketone **15** by anionic and thermal oxy-Cope rearrangement is described.

The oxy- Cope rearrangement is now firmly established as a most potent and versatile tool for synthetic organic chemists engaged in the construction of complex organic molecules.[1] The rearrangement is also constitutes an intrinsically sophisticated means of achieving internal chirality transfer within the context of polycyclic ketone construction. Variation of the substituents in the 3- hydroxy-1,5- hexadiene (basic oxy- Cope core system) will lead to products having well-defined networks. The ring systems capable of being accessed by the oxy-Cope process are increasing in the literature everyday.[2,3] As part of our ongoing research programme,[4] it was of interest to study the effect of halogen substitution on the alkynyl group of oxy-Cope moiety so that the process of rearrangement could provide an easy entry into bifunctional systems, which could be converted into the growing list of hydroazulenoid ring systems. The protocol defined herein for the oxy-Cope rearrangement, offers several advantages over strategies already known for assembling functional networks.

Hence, it was of interest to synthesize the cycloalkanone bromoalkynyl carbinol derivatives **2, 6, 10, 15** and to study their rearrangement behavior under different solvent and

nucleophilic base systems. The synthesis of compound **2** and its rearrangement study is represented in scheme **1**.

The bromoethynyl compound **2**, was synthesized from cyclopentane ethynyl derivative **1**.[4] Treatment of **1** in dry acetone with N-bromosuccinimide(NBS)[5] and catalytic amount of silver nitrate at room temperature afforded a solid **2** (m.p : 67-70 °C) after column chromatographic (Silica gel) purification. The bromoethynyl carbinol **2** thus obtained was fully characterized by spectral means. The IR spectrum of **2** showed a strong peak at 2200cm^{-1} for -C≡C- group and the absence of a peak at 3300 cm^{-1} indicates the absence of -C≡C-H in compound **2**. Its mass spectrum showed a molecular ion peak at *m/z* 328(M^+) and a M^++1 peak at *m/z* 329.



Reagents and Conditions:

a) NBS, $AgNO_3$(cat.), dry. acetone, 1h, rt, 90%. b) 4% KOH/EtOH, Δ, 1h, 45%,
c) PEG-200, reflux, 15min. , 46%, d) Transannular ene reaction.

Scheme 1

Rearrangement Studies

The rearrangement of compound **2** was carried out under the following conditions.

a) Rearrangement using nucleophilic base (4% KOH/EtOH)

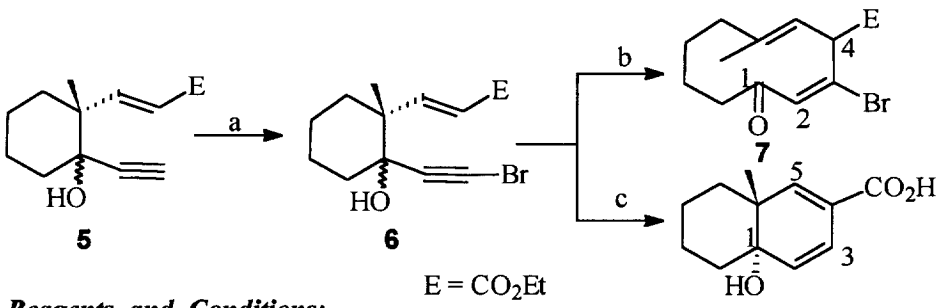
The rearrangement was effected by refluxing the bromoacetylenic compound **2** with aqueous KOH (4%, 5mL) in ethanol for 1h. Workup and purification of the residue by silica gel column chromatography gave a solid (m.p : 121-123 °C) in 45% yield. Spectral studies reveals that the compound is ester hydrolyzed, cyclised and rearranged compound. It showed

the following spectral features: The IR spectrum showed absorptions at 3560 (-OH), 1705 (-COOH) and 1635 (for double bond). Its ^{1}H NMR (90 MHz) showed a broad singlet at δ 3.5 indicating the presence of hydroxyl proton and a broad singlet at δ 9.8 indicating the presence of carboxylic acid proton (*cf.* scheme 1).

b) Rearrangement using PEG-200 (as solvent)

In order to understand the effect of solvent, polyethylene glycol-200 (PEG -200) was employed as solvent for the rearrangement of compound **2**. Refluxing compound **2** in PEG-200 for 15 min., work-up followed by column chromatographic (silica gel) purification afforded **4** in 46% yield (*cf.* scheme 1). Compound **4** was identified as the rearranged bicyclo[4.3.0] compound and was fully characterized by spectral means (*see experimental*).

The strategy for the synthesis of compound **6** and its rearrangement is schematically represented in Scheme 2.



Reagents and Conditions:

a) NBS, $AgNO_3$(cat.), dry. acetone, 1h, rt, 95 %, b) PEG-200, reflux, 15min., 66% (or) *o*-DCB, reflux, 12h, N_2, 68%, c) 4% KOH/MeOH, Δ, 1h, 53%,

Scheme 2

The bromoethynyl compound **6** was prepared in a manner similar to that described for compound **2** in 95% yield (*cf.* scheme 2). The bromoethynyl carbinol **6** thus obtained was fully characterized by spectral means. The IR spectrum showed the following absorption bands at 3560(OH), 2200(-C≡C-), 1720(ester carbonyl), 1640(enone carbonyl) cm^{-1}. The mass spectrum of the compound **6** showed a molecular ion peak at *m/z* 314(M^+) and a M^++1 peak at *m/z* 315.

Rearrangement Studies

The rearrangement studies of compound **6** were carried out under the following conditions.

a) Rearrangement using nucleophilic base (4% KOH/MeOH)

The rearrangement was effected by refluxing the bromoacetylenic compound **6** with aqueous KOH (4%, 5mL) in methanol for 1h. Workup and purification of the residue by silica gel column chromatography gave a solid (m.p : 121-123 °C) in 53% yield. Spectral studies of the compound reveals that the product is a rearranged compound with the ester group being hydrolyzed and bromine atom being lost (*cf.* scheme 2). It showed the following spectral features: The IR spectrum showed absorptions at 3560(-OH), 1710(-COOH), and 1635 (for double bond) cm^{-1}. Its ^1H NMR (90 MHz) showed a broad singlet at δ 9.8 indicating the presence of carboxylic acid proton and a broad singlet at δ 2.6 for hydroxyl proton. The mass spectrum showed a molecular ion peak at *m/z* 208 (M^+) which indicates the loss of bromine.

b) Rearrangement using o-DCB (as solvent)

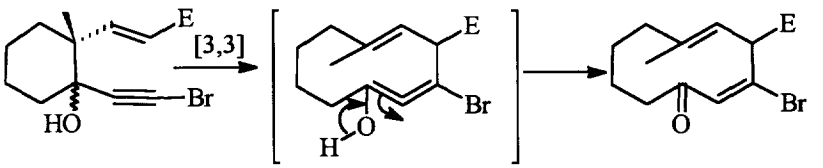
Since the rearrangement of compound **6** under conditions described above resulted in the ester being hydrolyzed and a debrominated product, the rearrangement was attempted with refluxing in *o*-DCB (high boiling, non nucleophilic). Rearrangement of **6** with *o*-DCB was carried out by refluxing it with *o*-DCB for 12h under N_2 atmosphere which afforded the rearranged compound **7** in 68% yield after column (silica gel) purification (*cf.* scheme 2). The IR spectrum of compound **7** showed the following absorption maxima : 1720 (ester carbonyl), 1705(ring carbonyl), 1640 (enone double bond) cm^{-1}. Mass spectrum of the compound **7** showed a molecular ion peak at *m/z* : 314(M^+) and a 315(M^++1) peak. Based on the above data the compound **7** was assigned a structure incorporating a medium-size ring system. The ^{13}C NMR of compound **7** showed peaks at δ 197.8 and 166.1 indicating the presence of two carbonyl groups.

c) Rearrangement using PEG-200 (as solvent)

In order to understand the effect of solvent, polyethylene glycol-200 (PEG -200, high boiling solvent) was employed for the rearrangement. Refluxing compound **6** in PEG-200 for 15 min. and work-up followed by column chromatographic (silica gel) purification afforded (the same compound in *o*-DCB case) **7** in 66% yield (scheme 2). The DEPT-135 studies of

compound **7** clearly indicate the presence of five CH_2 carbons, two CH_3 carbons and three CH carbons. Based on the above data the compound **7** was assigned the structure **7**.

The formation of ring enlarged compound **7** from **6** can be explained by mechanistic consideration as represented in scheme 3. Rearrangement of **6** would give the ring enlarged compound **7** *via* intermediate **6a**. The reason for not forming cyclised product can also be explained by PCMODEL MMX calculation studies. The energy minimized structure of **7** is reproduced below. The transannular gap between C-1 and C-6 carbon is 4.111 Å which is higher for such reactions. But in the case of cyclic product **4** obtained by the rearrangement of **2**, the transannular gap between C-1 and C-6 in the intermediate **3** is only 2.672 Å, and hence facile transannular cyclisation takes place (See fig. 1).



6 **6a** **7**

E = CO_2Et

Scheme 3

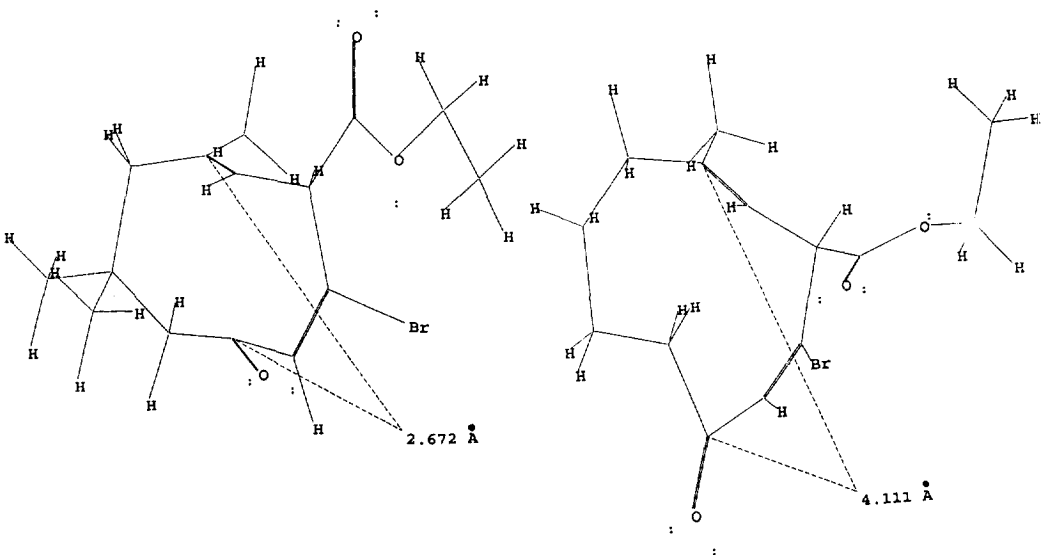
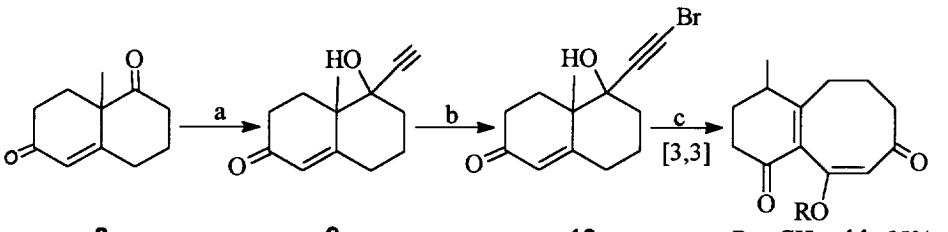


Fig. 1 The energy minimised structures of compounds 3 and 7

These rearrangement studies were extended to the Wieland-Meisher ketone bromoethynyl derivative **10** and is schematically represented in Scheme 4.



8 **9** **10**

R = CH_3, **11**, 55%

R = CH_2CH_3, **12**, 45%

Reagents and Conditions:

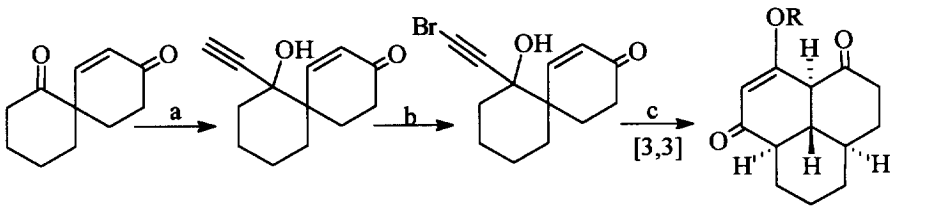
a) Li^+ $^-C{\equiv}CH$, THF, -78° C, 3h, 80 %, b) NBS, $AgNO_3$(cat.), dry. acetone, 40 min., rt, 84%.
c) R-OH, 4% KOH, 1h, reflux.

Scheme 4

Wieland-Meisher ketone[6a] **8** was ethynylated[6b] using 3 equivalents of lithium acetylide in THF at -78° C for 3h furnished the ethynyl derivative **9** in 80% yield as a solid (m.p: 172° C) and bromination of **9** with NBS as described for compounds **1** and **5** afforded compound **10** in 84% yield as a solid (m.p: 150-152° C) after silica gel column purification. Rearrangement of compound **10** was carried out by refluxing with nucleophilic bases (1) 4% KOH in methanol and (2) 4% KOH in ethanol for 1h, which yielded rearranged products **11** and **12** as a solids respectively. It is interesting to note here that the solvent used gets incorporated during the course of the rearrangement. This is the first report concerning such solvent incorporation during oxy-Cope rearrangement. The bicyclo[6.4.0] compounds **11** and **12**, thus obtained are basic structural units of many naturally occurring compounds like Neolemnanes[7] and Parvifolia[8] *etc.*, .

The success encountered in the rearrangement of bromoethynyl carbinols described above prompted us to extend this study to the bromoethynyl carbinol **15** incorporating a spiro system which is outlined in scheme 5.

The spiro compound **13** was prepared from 2-formyl cyclohexanone by Michael addition using methyl vinyl ketone (MVK) followed by cyclization using methanesulfonic acid[9] in 70% combined yield. Ethynylation of compound **13**, as described for compound **8** afforded compound **14** in 78% yield after chromatographic purification as a solid 124-126° C) and



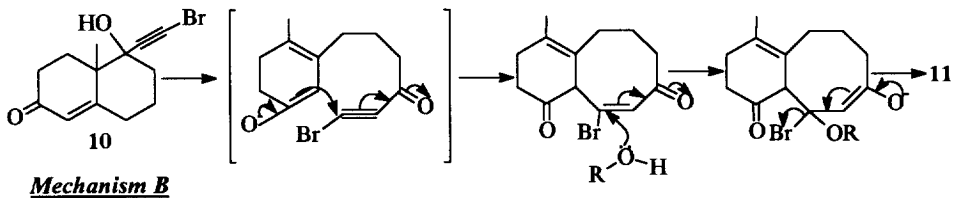
Reagents and Conditions:

a) Li^+ $^-C{\equiv}CH$, THF, -78° C, 3h, 78 %, b) NBS, $AgNO_3$(cat.), dry. acetone, 40 min., rt.
c) R-OH, 4% KOH, 1h, reflux, 25%.

Scheme 5

bromination of **14** as described earlier afforded the bromoethynyl derivative **15** which was found to be unstable during column purification. Its purity as checked by TLC and IR, was found pure enough for rearrangement. Rearrangement of compound **15** was carried out as described for compound **10** in methanol for 2h, which furnished the rearranged compound **16** in 25% yield as a solid (m.p: 162-164° C) after chromatographic purification. The structure for the rearranged product **16** was assigned based on analogy to the acetylenic anologue[10] and spectral data(*see experimental*). Two probable mechanisms (A and B) for the formation of compound **11** from compound **10** is depicted below(Fig. 2). With available evidence it is not possible to decide either of the mechanisms postulated.

Mechanism A



Mechanism B

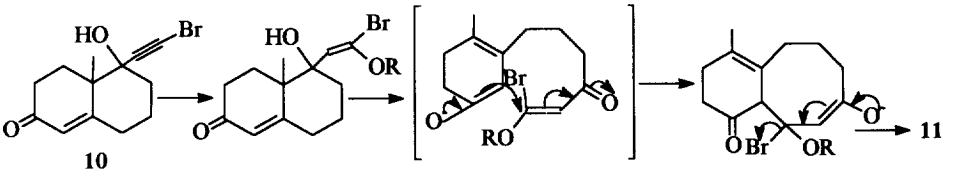


Figure 2

All the new compounds reported herein were completely analysed by spectral means. Further studies in this direction are underway.

EXPERIMENTAL SECTION

General Considerations

All melting points and boiling points are uncorrected. Infrared spectra were recorded on a Perkin-Elmer 598 spectrophotometer. ^{1}H NMR spectra were recorded either at 90 MHz on Varian EM-390 or at 200.1 MHz on BRUKER DPX 200 or at 400 MHz on JEOL GSX and ^{13}C NMR spectra were recorded at 50.3 MHz on a BRUKER DPX 200 or at 100.6 MHz on JEOL GSX or at 22.5 MHz on JEOL FX 90Q spectrophotometer as indicated. Chemical shifts are reported in ppm(δ) with TMS as standard and coupling constants are expressed in Hertz. Mass spectra were recorded on a JEOL JMS-DX 303 HF mass spectrometer. Elemental analysis was performed using a Perkin-Elmer 240B elemental analyzer. Thin layer chromatograms (TLC) were developed on glass plates coated with silica gel-G (ACME) of 0.25mm thickness and visualized with iodine. Column chromatography was carried out with SiO_2 (ACME, 100-200 mesh) using hexane-ethyl acetate mixture as eluent. For experiments dry glasswares used were thoroughly dried in an air oven, cooled and assembled under a stream of nitrogen. Anhydrous $MgSO_4$ was used for drying. Solvents were reagent grade and were purified according to literature procedure.[11] Unless otherwise stated all reported compounds were homogeneous liquids.

General procedure for ethynylation of 8 and 13: *Synthesis of* 9 *and* 14

Lithium acetylide was prepared by the addition of *n*-BuLi [prepared from lithium (0.7g, 0.1g atom) and *n*-BuBr (6.85g, 0.05 mol) in dry ether at 0 - 10 °C] to a dry THF solution of acetylene at -78 °C. To this was added a solution of ketone (2 g, 0.012 mol) in dry THF (25 mL) dropwise over 15 minutes and the reaction mixture was maintained at -78 °C for 3h with constant stirring. Solid K_2CO_3 (10g) was added to the reaction mixture followed by water (20 mL) and then extracted with ether (3 X 25 mL). The ether layer was washed with water, dried ($MgSO_4$) and concentrated at reduced pressure to furnish the ethynyl carbinol which was purified by column chromatography (silica gel).

***1 - Hydroxy - 1- ethynyl - 9 - methyl -Δ$^{5(10)}$octalin-6-one* 9**

Yield: 80%; m.p:172° C; R_f: 0.5 (9.5:0.5, hexane:ethyl acetate); IR ($CHCl_3$) ν_{max}, cm^{-1}: 3550 (OH), 3300 (-C≡C-H), 1660 (enone double bond); ^{1}H NMR (400 MHz, $CDCl_3$ / TMS) δ ppm

: 5.8(s, 1H, *vinylic proton*), 3.4(br s, 1H, OH), 2.5(s, 1H, *acetylenic proton*), 2.8-1.8(m, 10H, *methylenes*), 1.3(s, 3H, *angular methyl*).; ^{13}C NMR(100.6 MHz, $CDCl_3$/TMS) δ ppm : 197.7, 167.3, 125.0, 86.6, 76.8, 73.8, 44.1, 37.7, 34.4, 33.6, 30.2, 30.1, 16.7.; Mass spectra (*m/z*) : 204(M^+).

***1 - Hydroxy - 1- ethynyl spiro[5.5]-undec-7-ene-9-one* 14**

Yield: 78%; m.p:124-126° C; R_f: 0.4 (9.5:0.5, hexane:ethyl acetate); IR ($CHCl_3$) $\nu_{max.}$ cm^{-1}: 3480 (OH), 3300 (-C≡C-H), 1660 (enone double bond) ; ^{1}H NMR, (90 MHz, $CDCl_3$ / TMS) δ ppm :7.1(d, *J*=9.5 Hz, 1H, H_7), 6.0(d, *J*=9.5 Hz, 1H, H_8), 3.0(br s, 1H, OH), 2.6(s, 1H, *ethynyl proton*), 2.2-1.4(m, 12H, *methylenes*); Mass spectra (*m/z*) : 204(M^+).

***General procedure for the preparation of bromoethynyl compounds* 2, 6, 10 and 15**

To a solution of ethynyl carbinol (1g, 0.004 mol) in dry acetone (25mL) was added N-bromosuccinimide (1.047g, 0.0058 mol) and the contents were stirred for 10 minutes to get the clear solution. Silver nitrate (5-10 mg, catalytic amount) was added and stirring was continued for 45 minutes. Then the solvent was evaporated under *vacuo*. Carbon tetrachloride (25 mL) was added and the insoluble succinimide thus obtained was filtered off. Concentration of the filtrate under *vacuo* afforded a viscous liquid (CAUTION !, *Lachrymator*). The viscous liquid was further purified by column chromatography over silica gel using hexane : ethyl acetate (9.5:0.5) as eluent afforded the pure bromoacetylenic compounds.

***1β - Hydroxy - 1α - bromoethynyl - 2,4,4 - trimethyl - 2 (2'-carbethoxyvinyl) cyclopentane* 2**

Yield: 90% ; m.p : 67-70 °C; R_f : 0.5 (9.5:0.5, hexane:ethyl acetate); IR (CCl_4) $\nu_{max.}$ cm^{-1} : 3560 (-OH), 2200(-C≡C-), 1715 (ester carbonyl), 1640 (enone double bond); ^{1}H NMR (200.1MHz $CDCl_3$ / TMS) δ ppm: 1.1 (s,3H, CH_3), 1.2 (s, 3H, CH_3), 1.2 (s, 3H,CH_3), 1.3 (t, J=7.33, 3H, $COOCH_2CH_3$), 1.8 (m, 4H, *methylenes*),2.3 (br s, 1H, O*H*), 4.2 (t, J=7.33, 2H, $COOCH_2CH_3$), 5.9 (d, J=16.11,1H, H_7), 7.1 (d, J=16.11, 1H, H_6); ^{13}C NMR (50.3 MHz $CDCl_3$ / TMS) δ ppm: 166.7, 152.2, 121.2, 119.8, 81.5, 60.4, 54.2, 54.0, 50.8, 36.0, 33.3, 32.7, 25.9, 24.5, 14.2.; Mass spectra (*m/z*): 328 (M^+), 329(M^++1); Analysis: $C_{15}H_{21}O_3Br$ requires: C, 54.87; H, 6.45% Found: C 54.89; H, 6.40%.

***1 - Hydroxy - 1- bromoethynyl - 2 - methyl - 2 (2'-carbethoxyvinyl) cyclohexane* 6**

Yield: 95% ; R_f: 0.5 (9.5:0.5, hexane:ethyl acetate); IR (CCl_4) $\nu_{max.}$ cm^{-1}: 3560 (-OH), 2200 (-C≡C-), 1720 (ester carbonyl), 1640 (enone double bond); ^1H NMR (200.1 MHz, $CDCl_3$ / TMS) δ ppm : 1.1 (s, 3H, CH_3), [1.2(s, 3H, CH_3)], 1.3 (t, J=7.33, 6H, $COOCH_2CH_3$), 1.4-2.0 (m, 16H, H_6, H_5, H_4& H_3), 2.2 (br s, 2H, OH), 4.2 (q, J=7.33, 4H, $COOCH_2CH_3$), 5.8 (d, J=16.11,1H, H_8) [5.9 (d, J=16.11,1H, $H_{8'}$)], 7.3 (d, J=16.11, 2H, H_7&H_7); ^{13}C NMR(22.5 MHz, $CDCl_3$/TMS); δ ppm : 166.9, 154.3, 152.8, 121.0, 120.4, 82.2, 74.3, 73.6, 60.4, 46.0, 45.7, 44.6, 36.3, 35.6, 33.5, 33.2, 23.1, 22.2, 20.7, 20.5, 19.1, 14.2 .Thus ^1H NMR and ^{13}C NMR shows the presence of diastereomers in the ratio of 1:1. Mass spectra (*m/z*) : 314(M^+), 315(M^++1).

***1 - Hydroxy - 1- bromo ethynyl - 9 - methyl -$\Delta^{5(10)}$octalin-6-one* 10**

Yield: 84%; m.p:150-152° C; R_f: 0.5 (9.5:0.5, hexane:ethyl acetate); IR ($CHCl_3$) $\nu_{max.}$ cm^{-1}: 3450 (OH),2200 (-C≡C-), 1660 (enone double bond); ^1H NMR, (90 MHz, $CDCl_3$ / TMS) δ ppm :5.85(s, 1H, H_5), 3.65(s, 1H, *OH*), 2.48-2.02(m, 10H, *methylenes*), 1.3(s, 3H, *angular methyl*).; ^{13}C NMR(22.5 MHz, $CDCl_3$/TMS) δ ppm : 199.4, 167.0, 125.8, 82.0, 76.3, 47.5, 45.5, 35.0, 34.0, 30.3, 30.0, 22.2, 17.1; Mass spectra (*m/z*) : 284(M^++2;); Analysis: $C_{13}H_{15}OBr$ requires: C, 55.13; H, 5.34%; Found: C, 55.20; H, 5.31%.

General procedure for thermal oxy-Cope rearrangement using PEG-200 as solvent (Procedure A)

The bromoethynyl carbinol (0.005 mole) was refluxed in polyethylene glycol - 200 (PEG- 200, 5mL) for about 10-15 min. The solution was cooled and poured into water (250mL), and kept at room temperature for 20 min., and then extracted with ether (3 X 50 mL). The combined organic extract was washed with water and dried. Concentration of the organic layer under reduced pressure and purification through silica gel column afforded the rearranged compound.

General procedure for thermal oxy-Cope rearrangement using o-DCB as solvent (Procedure B)

A solution of bromoethynyl carbinol (0.005 mol) in *o*-DCB (20 mL) was refluxed under nitrogen atmosphere for 12h. The solution was cooled, and the solvent was removed under vacuum (0.5 torr), and the residue was chromatographed over silica gel [hexane - ethyl acetate (10:1)] to give the pure rearranged compound.

***3-bromo-4 - Carbethoxy -1α- hydroxy- 6β, 8, 8- trimethyl bicyclo [4.3.0] nona-2,4-diene* 4**

Following the general procedure A, compound **4** was obtained by the rearrangement of compound **2** in 46% yield as a liquid

R_f: 0.6(9.5:0.5, hexane:ethyl acetate); IR (CCl_4) $\nu_{max.}$ cm^{-1} :3520 (OH), 1730 (ester carbonyl), 1640 (double bonds); ^1H NMR (200.1 MHz, $CDCl_3$ / TMS), δ ppm :1.1(s, 3H, angular CH_3), 1.4(t, 3H, $CO_2CH_2CH_3$), 1.5 &1.7(s, 6H, $2CH_3$), 2.2-2.7(m, 4H, *methylenes*), 3.3(br s, 1H, *OH*), 4.2(q, 2H, $CO_2CH_2CH_3$), 6.4(s, 1H, H_2), 7.5(s, 1H, H_5); ^{13}C NMR(50.3 MHz, $CDCl_3$/TMS) δ ppm : 168.2, 142.4, 134.3, 124.3, 113.3, 112.8, 105.2, 80.2, 64.2, 58.3, 30.2, 29.5, 24.1, 20.1, 16.2. Mass spectra (*m/z*) : 328(M^+), 329 (M^++1); Analysis: $C_{15}H_{21}O_3Br$ requires: C, 54.87; H, 6.45% Found: C, 54.92; H, 6.38%.

***3-Bromo-4-carbethoxy-6-methyl deca-2,5-diene-1-one* 7**

Following the general procedure A, compound **7** was obtained by the rearrangement of compound **6** in 66% yield as a liquid and following the general procedure B, compound 7 was obtained by the rearrangement of compound **6** in 68% yield as a liquid.

R_f : 0.5 (9.5:0.5, hexane:ethyl acetate) ; IR (CCl_4) $\nu_{max.}$ cm^{-1} : 1720 (ester carbonyl), 1705(ring carbonyl), 1640 (enone double bond); ^1H NMR, (200.1 MHz, $CDCl_3$ / TMS) δ ppm : 1.3 (t, 3H, CH_3), 2.0(q, 1H, H_4), 2.3(s, 3H, *vinylic* CH_3), 2.5-2.9(m, 8H, *methylenes*), 4.3 (q, *J*=7.33, 2H, $COOCH_2CH_3$), 8.0 (s, 1H, H_5), 8.5 (s,1H, H_2); ^{13}C NMR,(50.3 MHz, $CDCl_3$/TMS) δ ppm: 197.8, 166.1, 147.4, 136.9, 134.9, 132.9, 128.5, 126.4, 61.1, 38.4, 26.7, 22.2, 19.4, 14.3; Mass spectra (*m/z*) : 314(M^+), 315(M^++1).; Analysis: $C_{14}H_{19}O_3Br$ requires: C, 53.35; H, 6.08% ; Found : C, 53.32; H, 6.10%.

General procedure for oxy-Cope rearrangement using nucleophilic base

To a solution of bromoethynyl carbinol (1g, 3.74 mmol) in methanol/ethanol (50 mL) was added slowly an aqueous solution of KOH(4% KOH, 5mL) and the solution was refluxed for 1h. The colour of the solution turns red from yellow during the course of the rearrangement. The solvent was removed under vacuum, the resultant crude product was taken up in dichloromethane(150 mL) and washed twice with distilled water and concentration to yield a crude material as a highly viscous liquid. Purification by column chromatography(Silica gel) using hexane: ethyl acetate as eluent yielded the rearranged product as solid.

Data for compound* 11 *(MeOH / 4% KOH as medium)

Yield: 55%; m.p:120-122° C; R_f: 0.5 (9.5:0.5, hexane:ethyl acetate); IR ($CHCl_3$) $\nu_{max.}$ cm^{-1}: 2930, 1675, 1630, 1600, 1450; ^1H NMR, (90 MHz, $CDCl_3$ / TMS) δ ppm :5.7(s, 1H, *vinylic proton*), 3.65(s, 3H, *-OCH_3*), 2.8-1.8(m, 11H, *methylenes*), 1.3(d, 3H, *angular methyl*).; ^{13}C NMR(22.5 MHz, $CDCl_3$/TMS) δ ppm : 199.3, 195.7,167.4, 166.5, 110.7, 56.1, 38.3, 34.3, 32.0, 31.0, 29.3, 26.0, 18.1; Mass spectra (*m/z*) : 234(M^+) ; Analysis: $C_{13}H_{18}O_3$ requires: C,71.76; H, 7.74% Found: C, 71.68; H, 7.79%.

Data for compound* 12 *(EtOH / 4% KOH as medium)

Yield: 45%; m.p:140-142° C; R_f: 0.5 (9.5:0.5, hexane:ethyl acetate); IR ($CHCl_3$) $\nu_{max.}$ cm^{-1}: 2900,1670, 1610, 1440, 1370; ^1H NMR, (90 MHz, $CDCl_3$ / TMS) δ ppm :5.6(s, 1H, *vinylic proton*), 3.9(q, 2H, *-OCH_2-*), 2.8-1.8(br m, 11H, *methylenes*), 1.4-1.2(m, 6H, *2 CH_3*).; ^{13}C NMR(22.5 MHz, $CDCl_3$/TMS) δ ppm : 200.7, 195.4, 166.8, 165.9, 110.8, 64.8, 38.2, 34.6, 32.2, 31.0, 29.6, 25.8, 22.0, 17.5; Mass spectra (*m/z*) : 248(M^+); Analysis: $C_{13}H_{18}O_3$ requires: C,72.55; H, 8. 11%; Found: C, 72.59; H, 8.06%.

Data for compound* 16 *(MeOH / 4% KOH as medium)

Yield: 25%; m.p:162-164° C; R_f: 0.5 (9.5:0.5, hexane:ethyl acetate); IR(KBr) $\nu_{max.}$ cm^{-1}: 2940, 1700, 1670, 1600, 1360.; ^1H NMR, (400 MHz, $CDCl_3$ / TMS) δ ppm : 5.42(s, 1H, *vinylic proton*), 3.73(s, 3H, *-OCH_3*), 3.36(d, *J*=6.0 Hz,1H, H_{12}), , 2.58-1.42(br m, 12H, *methylenes*), 1.13-1.01(m, 1H, *H_{13}*).; ^{13}C NMR (100.6 MHz, $CDCl_3$/TMS) δ ppm : 207.7, 200.1, 174.5, 104.0, 56.5, 46.1, 55.8, 41.7, 41.6, 35.7, 30.4, 28.0, 26.6, 20.7; Mass spectra (*m/z*) : 234(M^+); Analysis: $C_{13}H_{18}O_3$ requires: C,71.76; H, 7.74%; Found: C, 71.72; H, 7.73%.

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REFERENCES AND NOTES

1. (a)Paquette, L. A.; Doherty, A. M. *In Polyquinane Chemistry: Reactivity and Structure Concepts in Organic Chemistry*; Springer-Verlag: Berlin. **1989**, Vol. *26*.
(b) Sticher, O. in *"New Natural Products and Plant Drugs with Pharmalogical, Biological or Therapeutic Activity"*, ed. Wagner,G.; Woff, P. Springer-Verlag, Berlin, **1977**.
(c) HeathCock, C.H. in *"Synthesis of Natural Products"*, ed. Apsimon, T. Wiley, New York, **1973**, vol.*2* and vol. *5*.
(d) Porter, L. *Chem. Rev.*, **1967**, *67*, 441
(e) Hudlicky, T.; Kutchan, T.T.; Wilson, S.R.; Mao, D.T. *J. Am. Chem. Soc.*, **1980**, *102*, 6351.

2. (a) Lutz, R.P. *Chem. Rev.*, **1984**, *84*, 205 and references cited therein.
(b) Paquette, L. A. *Angew. Chem. Intern. Edn.(Eng).* **1990**, *20*, 609.
(c) Herdon, J.W.; Mc Millan, L. A.; Daitch, C.E. *Tetrahedron Lett.*, **1990**, *31*,4547.

3. (a) Snider, B.B. in *"Comprehensive Organic Synthesis"*, ed. Trost, B.M.; Fleming, I. Pergamon Press, Oxford, **1991**, vol.*2*, pp 527-561; vol.*3* , pp 379; vol.*1* , pp 880.
(b) Lorenc, L.; Raj Kovic, M.; Miloranovic, A.; Mihailovic, M. *J. Chem. Soc., Perkin Trans.1*, **1988**, 1495.
(c) Mez, H.G.; Rist, G.; Ermer, O.; Lorenc, L.; Kalvoda, J.; Mihailovic, M. *Tetrahedron*, **1990**, *46*, 3659.
(d) Still, W.C. *J. Am. Chem. Soc.*, **1977**, *99*, 4186. *ibid.*, **1979**, *101*,493.
(e) Clive, D.L.J.; Russel, C.G.; Suri, S.C. *J. Org. Chem.*, **1982**, *47*, 1632.
(f) Kato, T.; Kondo, H.; Nishino, M.; Tanaka, M.; Hata, G.; Miyaka, A. *Bull. Chem. Soc. Jpn.*, **1980**, *53*, 2925.

4. (a) Janardhanam, S.; Devan, B.; Rajagopalan, K. *Tetrahedron Lett.*, **1993**, *34*, 6761.
(b) Janardhanam, S.; Rajagopalan, K. *J. Chem. Soc., Perkin Trans.1*, **1992**, 2727.
(c) Janardhanam, S.; Shanmugam, P.; Rajagopalan, K. *Synth. Commun.*, **1993**, *23*, 311.
(d) Balakumar, A.; Janardhanam, S.; Rajagopalan, K. *J. Org. Chem.*, **1993**, *58*, 5482.
(e) Shanmugam, P.; Rajagopalan, K. *Synth. Commun.*, **1996**, *26*, 2119.

(f) Shanmugam, P.; Rajagopalan, K. *Tetrahedron*, **1996**, *52*, 7737.

5. Hofmeister, H.; Annen, K.; Laurent, H.; Wiechert, R. *Angew. Chem. Int. Ed. Eng.* **1984**, *23*, 727.
6. (a)Ramachandran, S.; Newman, M. S. *Org. Synth.*, Col. Vol. IV , 553.
   (b) Balakumar, A. *"Claisen and Allenic oxy-Cope Rearrangements"* Ph. D Thesis, University of Madras, December, **1992**.
7. Izhal, R. R.; Fencal, W.; Brucetagle,; Clardy, J. *Tetrahedron*, **1981**, *37*, 2569.
8. Bohlmann, F.; Zdero, C. *Chem. Ber.*, **1977**, *110*, 468.
9. Eaton, P. E.; Jobbe, P. G. *Synthesis*, **1983**, 796.
10. Ravikumar, V. T.; Rajagopalan, K.; Swaminathan, S. *Tetrahedron Lett*, **1985**, *26*, 6137.
11. Perrin, D.D.; Armarego, W.L.F. *Purification of Laboratory Chemicals*, 3rd edn ; Pergamon Press, New York, **1988**.

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