Tetrahedron Letters 53 (2012) 6527-6530

Contents lists available at SciVerse ScienceDirect

Tetrahedron Letters

journal homepage: www.elsevier.com/locate/tetlet

Synthesis of a novel bis-triquinane: a photochemical rearrangement in cyclohexadienone moiety resulting in aromatisation

Deepak Singh, Pradeep T. Deota*

Department of Applied Chemistry, Faculty of Technology & Engineering, The Maharaja Sayajirao University of Baroda, Vadodara 390 001, India

ARTICLE INFO

Article history: Received 20 August 2012 Revised 17 September 2012 Accepted 19 September 2012 Available online 2 October 2012

Keywords: Bis-triquinane 2,4-Cyclohexadienones Photoisomerisation Ring fission ODPM rearrangement

ABSTRACT

The first synthesis of the bird-shaped bis-triquinane **7**, possessing a fascinating molecular architecture from readily available materials 2,6-dimethyl phenol and cyclopentadiene has been reported. Pentasubstituted phenols **9** and **10** were isolated during attempted photochemical oxa di- π methane rearrangement of acetic acid 3-(9-acetoxy-7,9-dimethyl-8-oxo-3a,4,7,7a-tetrahydro-1*H*-4,7-ethano-inden-5-ylmethyl)-1, 5-dimethyl-6-oxo-cyclohexa-2,4-dienylester **4**, a fused bicyclic system connected with a 2,4-cyclohexadienone unit. A probable mechanism is proposed for aromatisation.

© 2012 Elsevier Ltd. All rights reserved.

Triquinane natural products are a subset of polyquinanes which constitute an important class of sesquiterpenoids.¹ Linear triquinane natural products are isolated from plants, microbes and marine organisms and they have been attracting continuous attention from synthetic chemists due to their promising biological activity and their role as building blocks for exotic molecular architecture.^{1,2} As a result, numerous strategies have been developed for the construction of the triquinane framework since its discovery in 1966.³

In this context we conceived a bird-shaped bis-triquinane molecule $C_{31}H_{36}O_6$ (Fig. 1), which is assembled through the union of two triquinane skeletons connected by a methylene group with



Figure 1. Energy minimised 'bird shape' skeleton of bis-triquinane 7.

inner carbon of peripheral cyclopropane ring to generate an array of a bird. Towards this we explored the photochemical rearrangement of bis-cycloadduct of type **5** to assemble hitherto unknown bis-triguinane **7**.

The precursors **4** and **5** were readily available in three steps from 2,6-dimethylphenol **1** as follows. Tetramethyl bisphenol-F **2** was obtained by the condensation of **1** with formaldehyde. The oxidative acetylation of **2** furnished bis-cyclohexadienone **3** which on cycloaddition with cyclopentadiene gave **4** as major and **5** as a minor product⁴ (Scheme 1).

The photochemical reactions have attracted great attention for their ability to act as a key step in the creation of complex molecular architecture and in various natural products syntheses.⁵ Photochemical reaction of rigid β , γ -unsaturated carbonyl systems has great synthetic potential.⁵ Compounds containing β , γ -enones undergo two unique reactions that are characteristic of their excited states. The triplet sensitised irradiation leads to a 1,2-acyl shift while direct excitation induces a 1,3-acyl shift.^{5,6}

Thus, when a solution of **5** in acetone both as a solvent and as a triplet sensitiser was irradiated with mercury vapour lamp (125 W) in a quartz immersion well for 2 h, the products **6** and **7** were isolated after the removal of solvent under reduced pressure followed by column chromatography (Scheme 2). The structures of the compounds were readily discernible through their FTIR, ¹H, ¹³C, DEPT-90, DEPT-135 NMR and mass analysis data.¹⁰ It was interesting to observe half number of signals in the NMR spectrum of **7** due to its symmetric structure.

Alternatively, it was envisioned that the bis-triquinane **7** could also be accessed through tandem photochemical-





^{*} Corresponding author. Tel.: +91 0265 2434188x415/212; fax: +91 0265 2423898.

E-mail address: deotapt@yahoo.com (P.T. Deota).

^{0040-4039/\$ -} see front matter @ 2012 Elsevier Ltd. All rights reserved. http://dx.doi.org/10.1016/j.tetlet.2012.09.077



Scheme 3.

thermal-photochemical protocol from precursor **4** as shown in Scheme 3. However attempted photochemical reaction of precursor **4** resulted in the formation of **9** as well as **10** and did not furnish the expected product **8**. The photochemical reaction of **4** in acetone for 0.5 h furnished product **9**.¹¹ It is interesting to note

that when the same reaction was continued for 1.5 h, additionally aryl substituted tetracycle **10** was also isolated however compound **8** was not obtained at all.¹² The photochemical aromatisation of cyclohexadienone moiety under these reaction conditions is hitherto unknown in the literature to the best of our knowledge.



Figure 2. ORTEP diagram of 9.



(a) $R^1, R^2 = CH_3, R^3, R^4 = H, b) R^1, R^2, R^4 = CH_3, R^3 = H, c) R^1, R^3 = CH_3, R^2, R^4 = H$

Scheme 4. Products reported from photochemical reactions of cyclohexadienones.



Scheme 5. Suggested mechanism of formation of 9 and 10.

Structure of **9** was established through its spectral data and by its single crystal X-ray analysis.⁷ The ORTEP diagram is shown in Fig. 2.

Hart et al. reported the photochemical transformation of 2,4-cyclohexadienone **11** by ring fission to give ketene **12** which thermally rearranges to a bicyclo[3.1.0]hexenone **13**.^{8a,b} Baldwin and Mcdaniel also investigated the photochemical reaction of 6-acetoxyclohexa-2,4-dienones **14**(**a**-**c**) and have proposed the formation of the open chain products **15**(**a**-**c**)^{8c} (Scheme 4).

The probable mechanism for the formation of **9** and **10** from **4** is outlined in Scheme 5. Photolytic ring cleavage converts cyclohexadienone **4** into **16** which perhaps rearranges to **17**.^{8a,b} The bicyclic ketone **17** may further give **9** via a series of steps.⁹

In this Letter, we have reported a novel synthesis of bis-triquinane and an unusual photochemical rearrangement of **4** in acetone to either **9** or a mixture of **9** and **10** with different time intervals.

Acknowledgments

We are thankful to Dr. S.M. Mobin, (IIT, Indore) for providing single crystal X-ray analysis. We also thank SAIF CDRI, Lucknow, for providing NMR spectra and Professor B.V. Kamath for providing GC–MS facility.

Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.tetlet.2012. 09.077.

References and notes

 (a) Mehta, G.; Srikrishna, A. Chem. Rev. 1997, 97, 671–719; (b) Singh, V. K.; Praveena, G. D.; Karki, K.; Mobin, M. S. J. Org. Chem. 2007, 72, 2058; (c) Mcclure, C. K.; Kiessling, A. J.; Link, J. S. Org. Lett. **2002**, *5*, 3811; (d) Singh, V.; Thomas, B. J. Org. Chem. **1997**, 62, 5310.

- (a) Mehta, G.; Nair, M. S. J. Am. Chem. Soc. 1985, 107, 7519; (b) Mehta, G.; Vidya, R. Tetrahedron Lett. 1998, 39, 6403.
- 3. Comer, F. W.; Trotter, J. J. Chem. Soc., Phys. Org. 1966, 1, 11.
- (a) Singh, D.; Deota, P. T. Synth. Commun. 2012, 43; (b) Deota, P. T.; Parmar, H. S.; Valodkar, V. B.; Upadhaya, P. R.; Sahoo, S. P. Synth. Commun. 2006, 36, 673; (c) Deota, P. T.; Upadhyay, P. R.; Parmar, H. S. Synth. Commun. 2005, 35, 1715.
- (a) Zimmerman, H. W.; Armesto, D. Chem. Rev. **1996**, 96, 3065; (b) Armesto, D.; Ortiz, M. J.; Agarrabeitia, A. R.; Noureddin, E. Angew. Chem., Int. Ed. **2005**, 44, 7739; (c) Armesto, D.; Ortiz, M. J.; Agarrabeitia, A. R.; Fontecha, M. Org. Lett. **2005**, 5. 2687.0LETVol.
- (a) Hoffmann, N. Chem. Rev. 2008, 108, 1052; (b) Bruce, J. Annu. Rep. Prog. Chem. Sect. B 2007, 103, 370; (c) Singh, V. K.; Vedantham, P.; Sahu, P. K. Tetrahedron 2004, 60, 8161; (d) Cheng, C. P.; Chen, C. H.; Chuang, G. J.; Liao, C. C. Tetrahedron Lett. 2009, 50, 3414; (e) Lee, T. H.; Rao, P. D.; Liao, C. C. Chem. Commun. 1999, 801; (f) Hsu, D. S.; Chou, Y. Y.; Tung, Y. S.; Liao, C. C. Chem. Eur. J. 2010, 16, 3121.
- 7. The single crystal data are deposited at Cambridge Crystallographic Data Centre and it has been allocated the deposition number CCDC 892381.
- (a) Hart, H.; Murray, R. K. J. Am. Chem. Soc. 1970, 35, 1970; (b) Hart, H.; Lankin, D. C. J. Org. Chem. 1968, 33, 4398; (c) Baldwin, J. E.; Mcdaniel, M. C. J. Am. Chem. Soc. 1968, 90, 6118.
- 9. Zimmerman, H. E. Angew. Chem., Int. Ed. 1969, 8, 4.
- 10. Synthesis of 6 and 7: A solution of precursor 5 (0.5 g 0.0009 mol) in acetone (600 ml) was irradiated for 2 h with a mercury vapour lamp of 125 W in a quartz photochemical reactor. The solvent was removed under reduced pressure to furnish a yellow solid which was chromatographed over a column of silica gel. Elution of column with petroleum ether/ethyl acetate (90:10) afforded compound 7 (0.146 g, 20%). It was interesting to observe half number of signals in the NMR spectrum due to its highly symmetrical structure. Mp = 252 °C.

IR (KBr): 2931, 3039, 1728 and 1234 cm^{-1} .

¹H NMŔ (400 MHz, CDCl₃): δ 5.69 (1H, m), 5.68 (1H, dd, $J_1 = 5.5$ Hz, $J_2 = 2$ Hz), 3.36 (1H, t, J = 2.4 Hz), 3.04 (1H, s, H- α to carbonyl), 2.91 (1H, superimposed dd, J = 7.6), 2.77 (1H, m), 2.54 (2H, m, CH₂ allylic), 2.07 (3H, s, acetatemethyl), 1.90 (1H, s, CH₂), 1.53 (3H, s, CH₃), 1.25 (3H, s, CH₃). ¹³C NMR (100 MHz CDCl₃): δ 206.78 (2 × C, CO), 170.22 (2 × C, OCOCH₃),

¹³C NMR (100 MHz CDCl₃): δ 206.78 (2 × C, CO), 170.22 (2 × C, OCOCH₃), 128.77, 127.55 (4 × C, olefinic), 80.47 (2 × C, attach to OCOCH₃), 64.26 (2 × C, Cq), 58.58, 53.46 (4 × C, CH), 51.73 (2 × Cq), 51.20 (2 × C, CH), 43.61, 38.40 (2 × C, CH₂), 35.30 (2 × C, CH), 21.98, 20.43, 15.72 (6 × C, CH₃).

Mass (EI⁺): *m*/*z* 504.14 M⁺, 443 (60.73%), 401 (100%), 228.14 (59.15%), 202 (88.30%).

Further elution of column with petroleum ether/ethyl acetate (85:15) furnished compound $\bf 6$ (0.164 g, 32 %).

Mp = 236 °C.

IR: (KBr): 3126, 2950, 1730, 1754, 1586 cm⁻¹.

¹H NMR (300 MHz, CDCl₃): δ 5.71 (2H, m), 5.70 (1H, s, β-H of enone group), 5.48 (2H, m), 3.52 (1H, s, CH bridgehead), 3.26 (1H, d, *J* = 8 Hz, CH), 2.99 (1H, m, CH superimposed with signal of CH₂), 2.93 (2H, m, CH₂), 2.76–2.39 (cluster of multiplets, 3H, CH), 2.12–2.35 (2H, m, CH₂), 2.07 (s, 6H, CH₃), 1.71–1.83 (2H, m, CH₂), 1.58 (3H, s, CH₃), 1.51 (3H, s, CH₃), 1.43 (1H, s, α-CH), 1.24 (3H, s, CH₃), 1.08 (3H, s, CH₃),

¹³C NMR (75 MHz CDCl₃): δ 207.86, 206.57 (2 × C, CO) 170.20, 169.42 (2 × C, OCOCH₃), 141.92, 133.76, 132.93, 131.06, 128.49, 124.76 (6 × C, olefinic), 88.87, 80.50 (2 × C, attach to OCOCH₃), 58.06, 57.58, 53.59 (3 × CH), 51.42 (Cq), 50.26 (CH), 48.62, 45.08 (2 × Cq), 42.16, 41.97 (2 × CH), 40.48, 38.23, 37.95 (3 × CH₂), 35.31 (CH), 22.17, 21.97, 21.57, 20.39, 17.11, 15.04 (6 × CH₃). Mass (EI⁺): m/z (%) 503.66 M⁺, 401.13 (22%), 269.78 (33.74%), 201 (90.73%), 186.18 (100%).

11. Synthesis of **9**: A solution of precursor **4** (0.5 g, 0.0011 mol) in acetone (600 mL) was irradiated for 0.5 h with a mercury vapour lamp in a quartz photochemical reactor. The solvent was removed under reduced pressure to give a crude yellow solid which was purified over a column of silica gel (petroleum ether/ethyl acetate 90:10) to furnish pure compound **9** (0.32 g, 64%).

Mp = 194 °C.

IR: (KBr): 3572, 2944, 1757 and 1486 cm⁻¹.

¹H NMR (300 MHz, CDCl₃): δ 6.70 (1H, s, CH), 5.70 (1H, m, cyclopentane), 5.46 (1H, m, cyclopentane), 5.19 (1H, bs, phenolic OH), 4.93 (1H, s, olefinic), 3.71 (1H, s, CH bridgehead), 3.20 (2H, s, CH₂), 2.86 (1H, m, CH₂), 2.73 (1H, m, CH₂), 2.47 (1H, m, CH), 2.27 (3H, s, CH₃), 2.16 (3H, s, CH₃), 2.05 (3H, s, CH₃), 2.00 (3H, s, CH₃), 1.78 (2H, superimposed dd, *J* = 3.9 Hz, CH), 1.50 (3H, s, CH₃), 1.18 (3H, s, CH₃).

 ^{13}C NMR (75 MHz CDCl₃): δ 207.12, 170.21, 168.98 (3 \times C, CO), 151.61, 146.40, 144.97, 133.82, 129.78, 128.27 (6 \times C, aromatic), 125.45, 121.24, 120.49, 116.65 (4 \times C, olefinic), 80.78 (1C, attach to OCOCH₃), 53.61 (1C, Cq), 51.34, 48.67, 38.27 (3 \times C, CH), 37.84, 35.71 (2 \times C, CH₂), 21.88, 20.47, 19.88, 15.74, 15.55, 9.76 (6 \times C, CH₃).

Mass (EI⁺): *m*/*z* (%) 438.16 M⁺, 279.12 (10.65%), 149 (100%).

12. Synthesis of 9 and 10: Precursor 4 (0.5 g, 0.0011 mol) was dissolved in acetone (600 ml) in a quartz photochemical reactor and irradiated for 1.5 h. The solvent was removed under reduced pressure to furnish a yellow solid which was chromatographed over a column of silica gel. Elution of column with petroleum ether/ethyl acetate (90:10) afforded compound 5-(4-hydroxy-2,3,5-trimethyl-benzyl)-7,9,9-trimethyl-3a,4,7,7a-tetrahydro-3H-4,7-ethano-inden-8-one 9 (0.146 g, 29%). Its identity was confirmed by completely matching mp, IR, ¹H and ¹³C NMR data with the compound 9 mentioned above. Further elution of column with petroleum ether/ acetate (85:15) afforded compound 10 (0.164 g, 32%).

Mp = 186 °C. IR: (KBr): 3282, 2976, 1757, 1716, 1481, 1444 cm⁻¹

¹H NMR (400 MHz, CDCl₃): δ 6.81 (1H, s, aromatic), 5.68 (2H, m, olefinic), 4.84 (1H, s, phenolic exchangeable OH), 3.14 (1H, s, methine), 3.04 (2H, m, methine), 2.36 (3H, s, CH₃), 2.31 (2H, m, CH₂), 2.19 (3H, s, CH₃), 2.06 (6H, s, 2CH₃), 1.72 (2H, s, CH₂), 1.63 (1H, d, *J* = 4.8 Hz, CH), 1.28(6H, s, 2CH₃).

 ^{13}C NMR (100 MHz CDCl₃): δ 209.48, 169.90, 169.10 (3 \times C, carbonyl), 151.67, 146.26 132.59, 130.83, 129.36, 122.48, (6 \times C, aromatic), 121.35, 116.70 (2 \times C, olefinic), 88.06 (1C, attach to OCOCH₃), 55.15, 54.82 (2 \times C, Cq), 49.90, 47.82, 45.91, 42.54 (4 \times C, CH), 38.02, 28.67 (2 \times C, CH₂), 21.67, 20.69,18.41, 17.53, 15.74, 9.88 (6 \times C, CH₃).

Mass (EI⁺): *m*/*z* 437.20 (M⁺).