forouz, and M. Ishiguro, *J. Am. Chem. Soc.*, preceding paper in this issue.

(19) NMR ($CDCl_3$) δ 0.90 (9 H, br s, CH_3), 1.04 (3 H, s, CH_3), 1.49, 1.56, 1.61, 2.32 (2 H, d, *J* = 3 Hz, $CH_2C{=}O$); IR (liquid film) 2980, 2950, 2890, 1722 (C=O), 1470, 1452, 1407, 1393, 1383, 1367, 1347, 1190, 1147, 1096, 1047, 1007 cm^{-1}.

(20) As a review of low-valent titanium reagent, see J. E. McMurry, *Acc. Chem. Res.*, **9**, 281 (1974).

(21) An attempted isolation of the intermediary imine was unsuccessful because of its extreme lability in protic solvent.

(22) Hexane was found to be the best solvent for the stereoselective reduction of imines; see ref 23.

(23) The details of this new procedure will be published elsewhere.

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(25) NMR ($CDCl_3$, XL-100) δ 0.72, 0.79, 0.84, 0.96, 0.97, 1.22, 3.81 (1 H, br m, CHNC=O), 5.5 (1 H, br m, NH), 7.92, 8.04, 8.18 ppm; IR (CCl_4) 1695 cm^{-1}.

(26) W. R. Hertler and E. J. Corey, *J. Org. Chem.*, **23**, 1221 (1958).

(27) A crude extract of *Hymeniacidon* sp., kindly provided from Professor P. J. Scheuer and Dr. F. Woolard, was purified by thin layer chromatography on silica gel using 1–2% ether in hexane as a developing solvent (five developments). 9-Isocyanopupukeanane thus obtained as a pale yellow liquid of reasonable purity was used for the comparison: NMR ($CDCl_3$, XL-100) of synthetic **1**, δ 0.80, 0.83, 0.86, 0.90, 1.03, 1.24, 3.26 ppm (1 H, br d, CHNC); NMR of the natural **1** contaminated by small peaks at δ 0.86, 0.95, 1.06, 1.54 ppm; IR (CCl_4) 2150 cm^{-1} (isocyanide); TLC (silica gel, 5% ether in hexane) R_f 0.45; LC, Altex 4.6 × 250 10 μ-Lichrosorb column, 5% ether in hexane, t_r 78 min.

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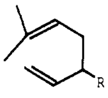
Tandem Cope–Claisen Rearrangement: A Contrathermodynamic [3,3] Sigmatropic Sequence

Sir:

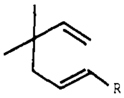
The Claisen rearrangement and to a lesser extent the Cope rearrangement have found substantial utility in the methodology of synthetic organic chemistry.[1] These rearrangements have been exploited in tandem (Claisen-Cope rearrangement[2]) in such a manner that the lower activation energy, irreversible Claisen rearrangement generates a 1,5-hexadiene which permits a subsequent, higher activation energy, reversible Cope rearrangement to proceed. The aldehyde produced (in the case of vinyl ether rearrangements) depends upon the position of the Cope equilibrium and, in general, is the 1,5-hexadiene with the more highly substituted double bonds.

To our knowledge this tandem sequence has not been practiced in the opposite sense, whereby the Cope triggers the Claisen rearrangement. We report here that this reaction sequence is *viable and that it serves to shift unfavorable Cope equilibria by an irreversible Claisen rearrangement.*

Thermolysis[3] of ester **1a**[4,5] at 275 °C provided an equilibrium mixture of esters **1a** and **2a** (K_{eq}(**2a**/**1a**) = 0.25). Although well suited for eventual Claisen rearrangement via the sequence **1a** → **2a** → **2b** → **2c** → **3**, ester **2a** is the minor component in the equilibrium. This difficulty was circumvented by transforming ester **1a** into vinyl ether **1c** by sequential $LiAlH_4$ reduction and vinylation. Rearrangement of **1c** in a flow system (hexane, N_2, 525 °C, 10 s) gave rise to the aldehyde **3** in 57% yield.

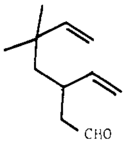


1

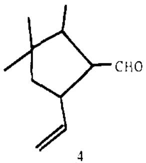


2

a, R = $CO_2C_2H_5$
b, R = CH_2OH
c, R = $CH_2OCH{=}CH_2$

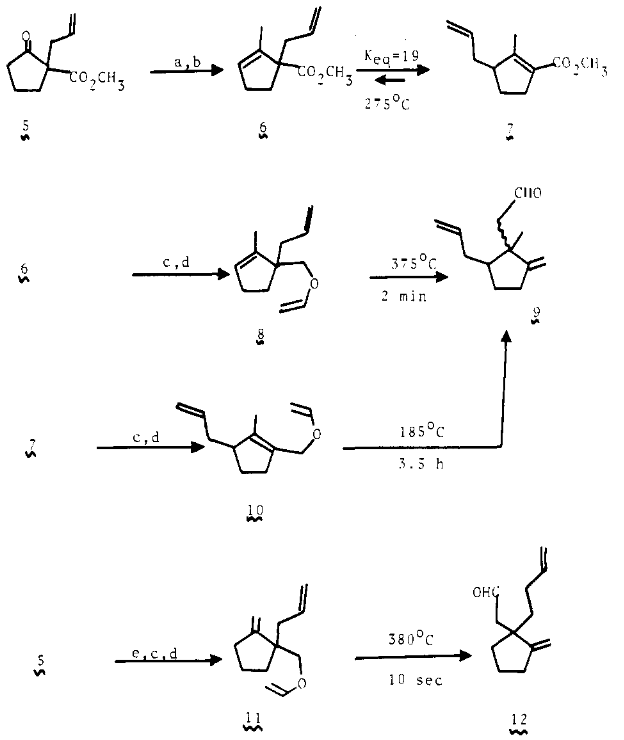


3



4

Scheme I[a]



[a] a, CH_3MgBr; b, $H_2C_2O_4 \cdot 2H_2O$, $C_6H_5CH_3$, Δ; c, $LiAlH_4$, Et_2O; d, $C_2H_5OCH{=}CH_2$, $Hg(OAc)_2$; e, $(C_6H_5)_3P{=}CH_2$, Me_2SO.

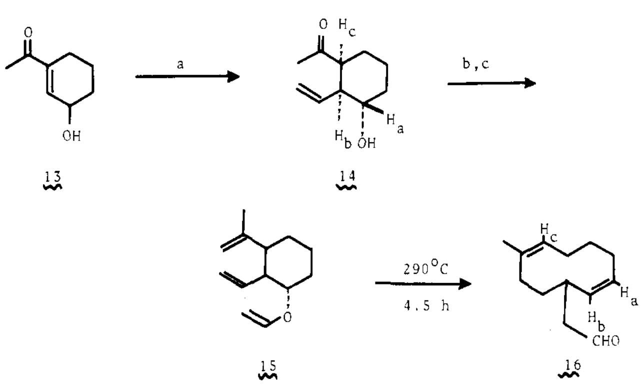
When the rearrangement was performed in a sealed tube (375 °C, 4 min) the aldehyde **3** was formed as the major product: IR (CCl_4) 2710, 1726, 1638 cm^{-1}; NMR ($CDCl_3$, 270 MHz) δ 9.65 (t, 1 H, *J* = 2 Hz), 5.84–5.63 (2 H, m), 5.04–4.88 (4 H, m), 2.79–2.68 (1 H, m), 2.44–2.36 (2 H, m), 1.53–1.33 (2 H, m), 1.03 (3 H, s), 1.02 (3 H, s). The aldehyde **4** (14%) was also formed in the reaction along with an unidentified (6%) aldehyde. Aldehyde **4** was independently shown to arise from **3** (325 °C, 2 h) via Conia rearrangement.[6]

The vinyl ether **8**, prepared as outlined in Scheme I, was rearranged to a diastereomeric mixture (55:45) of aldehydes **9**: 87%; IR (CCl_4) 2725, 1719, 1638 cm^{-1}; NMR ($CDCl_3$, 90 MHz) δ 9.69 (≈ 0.5 H, t, *J* = 3.3 Hz, 270 MHz), 9.66 (≈ 0.5 H, d,d, *J* = 2.4, 2.5 Hz, 270 MHz), 6.00–5.51 (1 H, m) 5.16–4.74 (4 H, m), 1.22 and 0.98 (3 H, 2s). The vinyl ether **10** containing 5% **8** was subjected to Claisen rearrangement at 185 °C to produce a nearly identical mixture of diastereomers.[7] A 50:50 ratio of isomers of the congeneric esters of **9** was obtained[8] when the precursory alcohol of **10** was subjected to the orthoacetate Claisen rearrangement conditions[9] (140 °C). These data reveal a $\Delta\Delta F^{\ddagger}$ which is temperature insensitive over the temperature range studied.[10]

Vinyl ether **11** (Scheme I) gave rise to a single aldehyde **12** (91%; IR (CCl_4) 2721, 1720, 1640 cm^{-1}; NMR ($CDCl_3$, 90 Mz) δ 9.73 (1 H, t, *J* = 3 Hz), 6.02–5.54 (1 H, m), 5.15–4.73 (4 H, m), 2.44 (2 H, d, *J* = 3 Hz)) when heated for a short period of time. Prolonged heating gave rise to secondary products.

The equilibrium between 1,2-divinylcyclohexanes and 1,5-cyclodecadienes is one which generally lies to the side of the former and manifests itself in natural products chemistry in the elemane-germacrane equilibrium.[11] The Cope-Claisen rearrangement serves as a means of preparing functionalized

Scheme II[a]



[a] a, $(CH_2{=}CH)_2CuLi$, Me_2S, THF; b, $C_2H_5OCH{=}CH_2$, $Hg(OAc)_2$; c, $(C_6H_5)_3P{=}CH_2$, THF.

cyclodecadienes.

Hydroxyenone **13**[12] (Scheme II) provided **14**[13] (mp 70-71 °C; NMR ($CDCl_3$, 270 MHz) δ 5.90-5.74 (1 H, m), 5.19-5.07 (2 H, m), 4.10-4.00 (1 H, m, H_a), 3.01 (dt, J = 8, 4 Hz, H_c), 2.53 (dt, J = 9, 5 Hz, H_b), 2.11 (3 H, s)) upon stereoselective cuprate[14] addition and kinetic protonation of the resultant enolate. The derived triene **15** was converted to (2*Z*,7*Z*)-8-methylcyclodecadien-1-acetaldehyde (**16**) in 55% yield (Scheme II):[15] IR (neat) 2707, 1721, 748, 725 cm^{-1};[16,17] NMR ($CDCl_3$, 270 MHz) δ 9.64 (1 H, t, J = 2 Hz), 5.33 (1 H, dt, J = 4, 11 Hz, H_a), 5.05 (2 H, m, H_b, H_c), 1.69 (3 H, s). Extensive decoupling of the NMR spectrum supported the armchair[18] conformation of **16**.

Since the *Z,Z* isomer is the thermodynamically most stable of the 1,6-cyclodecadienes,[18] we are not able to rule out at this time the possibility that diradicals are involved in the formation of **16** as opposed to a concerted pathway. The stereochemical consequences of this and related Cope-Claisen rearrangements and their application to natural products synthesis are under investigation.

Acknowledgment. We express our thanks to the National Institutes of Health (CA 16432) and Hoffmann-La Roche for financial support of this work. The Bruker 270-MHz NMR instrument is supported by National Institutes of Health Research Grant No. 1-P07-PR00798 from the Division of Research Sources.

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(15) VPC yield. In addition to **16**, two unidentified aldehydes (9%) and olefinic products of elimination (12%) accounted for all distillable products.

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(19) National Institutes of Health Career Development Awardee, 1973–1978.

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Analysis of Monolayer Films at the Air-Water Interface by Field Desorption Mass Spectrometry

Sir:

The direct sampling of surfactant molecules in monolayer films at the air-water interface using a conventional field emitter[1] and subsequent recording of their field desorbed mass spectra are demonstrated for the first time. The technique has proven applicable to a variety of surface films whose components differ in molecular weight and molecular charge.

Renewed interest in studying chemical reactions occurring in surfactant monolayer arrays has been promoted by the development of sensitive instrumental methods allowing the detection, separation, and characterization of the small amounts of materials, $\sim 10^{-9}$–10^{-10} mol/cm^2, contained in such films. Recently, applications of the following analysis methodologies have been reported: absorption and emission spectrometry,[2,3] infrared spectrometry,[4-6] vapor phase chromatography,[7] and high performance liquid chromatography.[8,9] An important piece of characterization information previously unavailable has been the molecular weight of the surfactant reaction products.

Field desorption mass spectrometry (FD MS) has proven a relatively mild technique for obtaining molecular ions of nonvolatile substances, including salts of ionizable organic compounds as well as high molecular weight monomeric and oligomeric compounds, with little or no fragmentation.[10] Normally, a field ion emitter, prepared according to the procedure of Schulten and Beckey,[1] is immersed in a solution containing the compound to be analyzed and introduced into the FD ion source, a high field is applied, and the desorbed, positively charged ions are mass analyzed and detected. In the present work, the hydrophobic emitter is simply dipped once in and out of a monolayer covered air-water interface and analyzed using a Varian-Mat 731 mass spectrometer equipped with an electron impact/field ionization/field desorption (EI/FI/FD) source operated in the FD mode. Potentials of +8 and −4 kV were applied to the field emitter and extraction element, respectively. A summary of the results for the surfactant compounds which have been examined in this manner is given in Table I and a typical spectrum is shown in Figure 1.

An upper limit to the amount of surfactant film transferred

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