Pergamon

Tetrahedron Vol. 50, No. 40, pp. 11709-11720, 1994
Elsevier Science Ltd
Printed in Great Britain
0040-4020/94 $7.00+0.00

0040-4020(94)00724-1

Heterogeneous Permanganate Oxidations: Synthesis of Medium Ring Keto-Lactones *via* Substituent Directed Oxidative Cyclisation

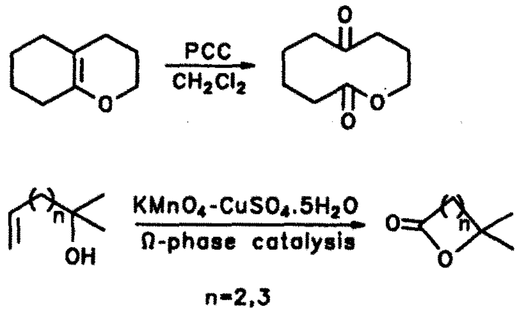
Jagattaran Das and Srinivasan Chandrasekaran*

Department of Organic Chemistry, Indian Institute of Science
Bangalore - 560 012, INDIA

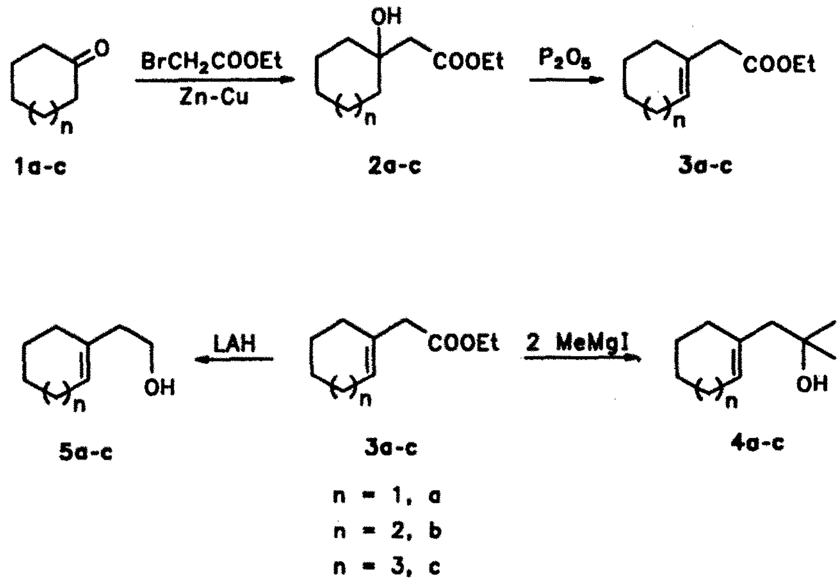
Abstract: Homoallyl alcohols 4a-b and 5a-b undergo smooth oxidative cyclisation to give the corresponding ring enlarged keto-lactones under heterogeneous permanganate oxidation conditions.

Macrolides, a class of cyclic lactones, are known for their biological activity.[1,2] The macrolide antibiotics are, of course, of immense pharmacological importance.[3] The chemistry of medium ring lactones has also attracted considerable attention because many of the molecules belonging to these groups have revealed diverse and significant biological activity.[4] There are numerous methods available for the synthesis of medium ring lactones and each one of these has its own advantages and limitations. The most common method involving intramolecular cyclisation of Ω-hydroxy carboxylic acid is entropically disfavored and the process becomes complicated due to intermolecular reactions.[1] The concept of cleaving fused double bond of a bicyclic structure to create larger ring has been demonstrated by several groups.[5] A similar strategy of cleaving the enol-ether double bond of a bicyclic system to give a ring enlarged keto-lactone using pyridinium chloro chromate has been reported from our laboratories[6] (Scheme 1).

The rate of heterogeneous reactions catalyzed by phase transfer reagents has been shown to be enhanced by the addition of catalytic amounts of water. A new non-classical phase transfer system, i.e. Ω-phase has been invoked to explain the role of water in these reactions.[7] Recently, we have reported[8] the involvement of Ω-phase catalysis in the direct oxidation of alkenes to α-hydroxy ketones/α-diketones with a mixture of potassium permanganate and copper sulphate in the presence of catalytic amount of water and



Scheme 1



Scheme 2

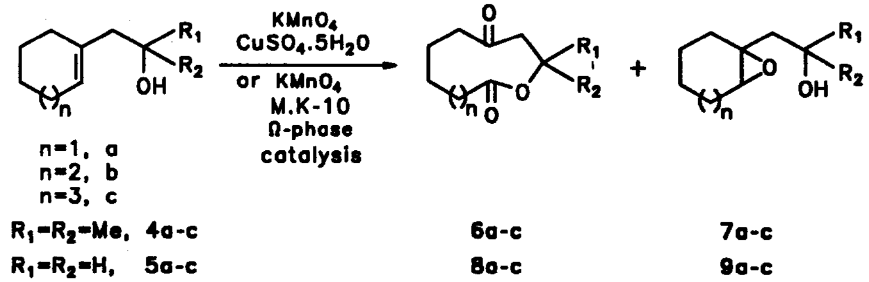
tert-butyl alcohol. It is believed that in this case *tert*-butyl alcohol acts as a phase transfer catalyst and the alcohol together with water forms the third phase over the surface of the inorganic solid in which the reaction takes place. One interesting observation in these oxidations is the formation of epoxides as the major or only product in the case of lipophilic olefins or Δ^5-unsaturated steroids respectively.[8,9] While exploring further the application of this reagent system, it has been observed that γ- and δ-hydroxy alkenes can be oxidatively cyclised to the corresponding γ-and δ-lactones[10] (Scheme 1).

These results prompted us to apply the oxidative cyclisation methodology on homoallyl alcohols like **4** and **5** where the olefin is part of a cyclic system (Scheme 2).

RESULTS

The substrates 4a-c and 5a-c have been synthesized following a three step strategy (Scheme 2). All the substrates have been subjected to oxidation with $KMnO_4$ supported on either $CuSO_4.5H_2O$ or montmorillonite K-10 under the conditions of Ω-phase catalysis (Scheme 3).

Our results are summarized in Table 1.



Scheme 3

DISCUSSION

From the results obtained it is evident that the *tert*-alcohols (entries 1 & 2, Table 1), in general, undergo smooth oxidative cyclisation with $KMnO_4$- $CuSO_4.5H_2O$ under omega phase catalysis to lead to medium ring keto-lactones as the major product with the corresponding epoxides as the minor product. The same substrates undergo oxidation with montmorillonite K-10 as the solid support to yield almost exclusively the keto-lactones (entries 4 & 5).

Table 1

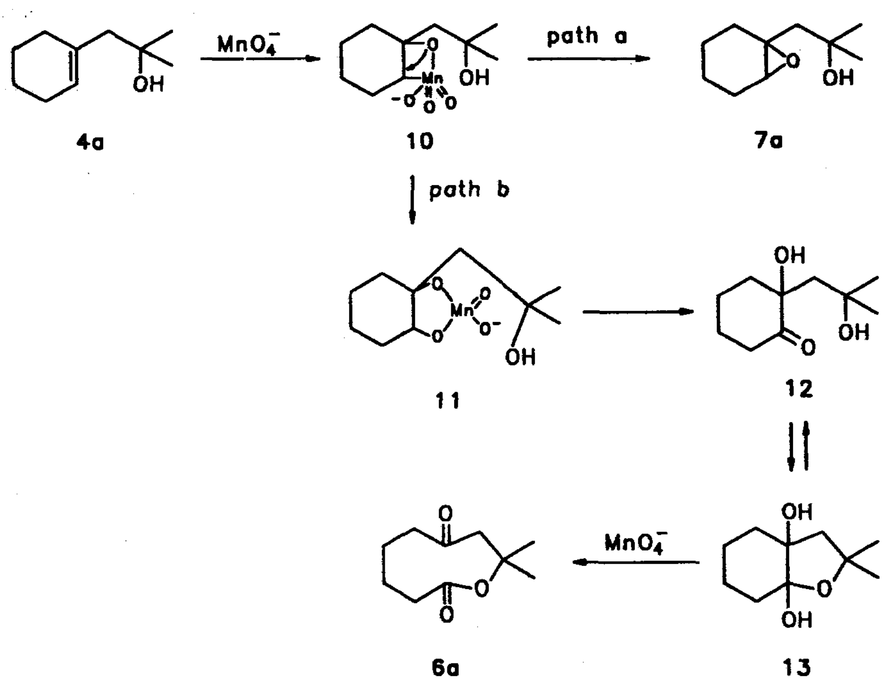
Entry	Substrate	Product/s	Oxidant	Time (h)	Yield (%)
1	4a	6a + 7a (46 : 1)	$KMnO_4 - CuSO_4.5H_2O$	4	47
2	4b	6b + 7b (3 : 2)	-"-	4	46
3	4c	6c + 7c (1 : 10)	-"-	4	56
4	4a	6a	$KMnO_4 - M.K - 10^*$	4	52
5	4b	6b + 7b (11 : 1)	-"-	4	49
6	4c	6c + 7c (1 : 1.7)	-"-	4	47
7	5a	8a	$KMnO_4 - CuSO_4.5H_2O$	5	32
8	5b	8b	-"-	6	30
9	5c	9c	-"-	3	15
10	5a	8a	$KMnO_4 - M.K - 10^*$	5	35
11	5b	8b	-"-	6	29
12	5c	9c	-"-	3	12

* M. K -10 refers to montmorillonite K-10

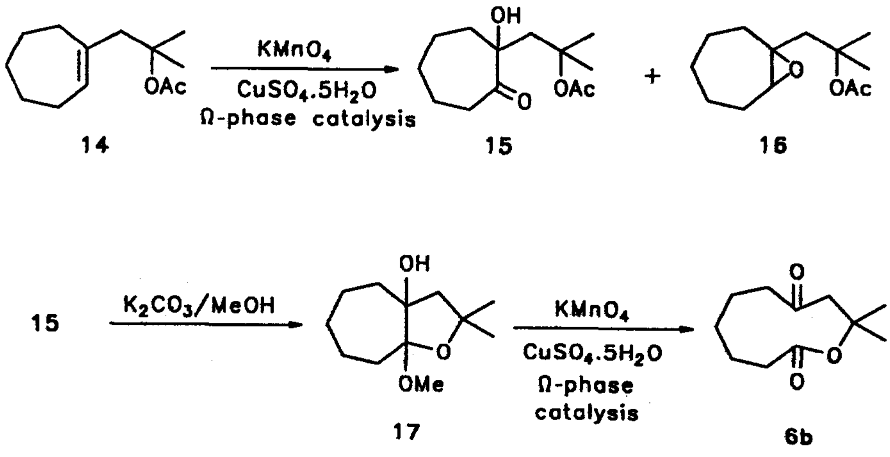
Unlike the oxidation of six- and seven- membered ring derivatives, the cyclooctene derivative **4c** (entries 3 & 6) yields the epoxide as the major product irrespective of the solid support.

The corresponding oxidative cyclisation of *primary*-alcohols (entries 7,8 & 10,11) generally yield only the keto-lactones, albeit in low yields. As pointed out earlier cyclooctene derivative **5c** (entries 9 & 12) yields mainly the epoxide as major product.

The oxidation of *tert*-alcohols **4a-c** with $KMnO_4$-$CuSO_4.5H_2O$ reveals some interesting results. While the alcohol **4a** containing a six membered ring undergoes smooth oxidative cyclisation to produce the keto-lactone **6a** as the major product, the alcohol **4c**, a cyclooctane derivative yields the epoxide **7c** as the major product providing a complete switch over in selectivity. In the case of alcohol **4b** the selectivity is lost (Table 1). This observation also lends support to the fact that more lipophilic substrates tend to form epoxide as the major product under omega phase catalysis.



Scheme 4



Scheme 5

Similar trend is also observed in the oxidation of compounds **4a-c** with $KMnO_4$-montmorillonite K-10. But in these oxidations the epoxide formation is reduced considerably compared to the oxidation with $KMnO_4$-$CuSO_4.5H_2O$. This observation is quite interesting and is probably due to the slightly acidic nature of the montmorillonite clay.

In order to understand this reaction better and to find out whether the epoxides could be precursors to the medium ring keto-lactones, epoxides **7a** as well as **7b** were allowed to react in separate experiments with $KMnO_4$-$CuSO_4.5H_2O$ (RT, 4 h). The substrates remained unaffected and the formation of the corresponding keto-lactones were not detected. This clearly demonstrated that the formation of epoxide and the keto-lactone were probably taking place *via* different pathways and that the epoxide was not an intermediate in the formation of the keto-lactone.

The formation of epoxide as well as keto-lactone can be rationalized according to the mechanistic pathway suggested in Scheme 4. The alcohol **4a** initially forms the metallooxetane **10**[11] which can be a common intermediate for the epoxide **7a** and for the keto-lactone **6a**. The metallooxetane **10** then can rearrange to either epoxide **7a** (path a) or to α-hydroxy ketone **12** *via* the cyclic manganate ester **11** (path b). It is possible to visualize the α-ketol **12** in equilibrium with the cyclic acetal **13** which can then undergo oxidation of the 1,2 diol moiety to lead to the keto-lactone **6a**.

In order to find out the possible involvement of α-ketol in the formation of the keto-lactone, acetate **14** was treated with $KMnO_4$-$CuSO_4.5H_2O$ under the conditions of omega phase catalysis. Ketol acetate **15** (31%) was isolated from this oxidation along with epoxide **16** (17%). Treatment of ketol acetate **15** with anhydrous potassium carbonate in dry methanol yielded cyclic acetal **17**. Acetal **17** on oxidation with $KMnO_4$-$CuSO_4.5H_2O$ produced keto-lactone **6b** (Scheme 5).

Thus, in this paper we have shown that a simple strategy of oxidative cyclisation can be utilized for the synthesis of medium ring keto-lactones starting from cycloalkanones in four steps by the use of permangante ion.

EXPERIMENTAL

^1H and ^{13}C NMR spectra were recorded on JEOL FXQ 90 MHz and 22.6 MHz respectively. IR spectra were recorded on Perkin Elmer model-781 spectrophotometer. Mass spectra were recorded on JEOL JMSD-300 spectrometer. Boiling points refer to the bath temperature and are uncorrected. TLC was performed on 0.25mm E. Merck precoated silica gel plates (60F-254). Silica gel (230-400 mesh) supplied by Merck was used for flash chromatography. Petroleum ether (60-80) was used for flash chromatography.

Preparation of β-Hydroxy Esters 2a-c[12]

Reformatsky reaction of cycloalkanones **1a-c** (20 mmol) with bromo ethylacetate (25 mmol) produced the corresponding β-hydroxy esters **2a-c**.

Hydroxy Ester 2a. Yield, 84%, b.p. 84°C/1 mm;(lit.,[12] b.p. 86-89°C/2 mm); IR (neat/cm^{-1}) 3520, 1713; ^{1}H NMR (90 MHz; $CDCl_3$) 1.29 (3 H, t, *J* 7.2), 1.44-1.76 (10 H, m), 2.36 (2 H, s), 2.92 (1 H, s) 4.06-4.30 (2 H, q).

Hydroxy Ester 2b. Yield, 96%, IR (neat/cm^{-1}) 3496, 2908, 2854, 1715; ^{1}H NMR (90 MHz; $CDCl_3$) 1.28 (3 H, t), 1.44-1.76 (12 H, m), 2.48 (2 H, s), 3.48 (1 H, s), 4.04-4.30 (2 H, q); Anal Calcd for $C_{11}H_{20}O_3$: C, 65.97, H, 10.06; Found, C, 65.72, H, 9.92.

Hydroxy Ester 2c. Yield, 91%, IR (neat/cm^{-1}) 3496, 2908, 1713; ^{1}H NMR (90 MHz; $CDCl_3$) 1.28 (3 H, t), 1.40-2.00 (14 H, m), 2.48 (2 H, s), 3.41 (1 H, s),4.04- 4.28 (2 H, q); Anal Calcd for $C_{12}H_{22}O_3$: C, 67.25, H, 10.35; Found, C, 67.35, H, 10.44.

Preparation of Unsaturated Esters 3a-c

Dehydration of hydroxy esters **2a-c** (14 mmol) were carried out in dry benzene (10 mL) under reflux on a water bath (3 h) using phosphorus pentoxide (2 g) as the dehydrating agent to yield the corresponding unsaturated esters **3a-c**.

Ester 3a. Yield, 73%, b.p. 93-95°C/10 mm (lit.,[13] b.p. 100°C/12 mm); IR (neat/cm^{-1}) 2972, 2930, 2890, 1737; ^{1}H NMR (90 MHz; $CDCl_3$) 1.27 (3 H, t),1.48-1.80 (4 H, m), 1.88-2.16 (4 H, m), 2.94 (2 H, s), 4.02-4.25 (2 H, q), 5.66 (1 H, br s).

Ester 3b. Yield, 79%, b.p. 98-100°C/7mm (lit.,[14] b.p. 104-107°C/12 mm); IR (neat /cm^{-1}) 2960, 2916, 2860, 1732; ^{1}H NMR (90 MHz; $CDCl_3$) 1.25 (3 H, t), 1.40-1.80 (6 H, m), 2.00-2.28 (4 H, m), 2.98 (2 H, s), 4.00-4.24 (2 H, q), 5.68 (1 H, t).

Ester 3c. Yield, 69%, (100-103°C/3 mm, lit.,[15] b.p. 81-83°C/0.7 mm), IR (neat/cm^{-1}) 2908, 2848, 1734; ^{1}H NMR (90 MHz, $CDCl_3$) 1.25 (3 H, t), 1.48 (8 H, br s), 2.00-2.32 (4 H, m), 2.98 (2 H, s), 4.00-4.20 (2 H, q), 5.51 (1 H, t).

Preparation of tert-Homo Allyl Alcohols 4a-c

Unsaturated esters 3a-c (5 mmol) were treated with two equivalents of methyl magnesium bromide to yield the *tert*-alcohols 4a-c.

Alcohol 4a.[16] Yield, 82%, IR (neat/cm^{-1}) 3430, 2965, 2930, 1380; ^{1}H NMR (90 MHz; $CDCl_3$) 1.22 (6 H, s), 1.48-1.68 (4 H, m), 1.96-2.16 (6 H, m), 5.49 (1 H, br s).

Alcohol 4b.[16] Yield, 87%, IR (neat/cm^{-1}) 3376, 2908, 2842, 1659; ^{1}H NMR (90 MHz; $CDCl_3$) 1.22 (6 H, s), 1.36-1.44 (6 H, m), 2.19 (6 H, m), 5.65 (1 H, t).

Alcohol 4c.[16] Yield, 92%, IR (neat/cm^{-1}) 3376, 2908, 2848, 1470; ^{1}H NMR (90 MHz; $CDCl_3$) 1.22 (6 H, s), 1.48 (8 H, s), 2.14 (6 H, br s), 5.43(1 H, t).

Preparation of primary-Homo Allyl Alcohols 5a-c

Reduction of unsaturated esters 3a-c (5 mmol) with lithium aluminium hydride (5 mmol) produced *primary*-homo allyl alcohols 5a-c.

Alcohol 5a.[17] Yield, 90%, IR (neat/cm^{-1}) 3322, 2908, 1943, 1044; ^{1}H NMR (90 MHz; $CDCl_3$) 1.40-1.76 (4 H, m), 1.84-2.08 (4 H, m), 2.21 (2 H, t), 3.66 (2 H, t), 5.52 (1 H, br s).

Alcohol 5b.[18] Yield, 92%, IR (neat/cm^{-1}) 3310, 2908, 2842, 1446, 1041; ^{1}H NMR (90 MHz; $CDCl_3$) 1.28-1.80 (6 H, m), 2.00-2.30 (6 H, m), 3.63 (2 H, t), 5.65 (1 H, t).

Alcohol 5c.[19] Yield, 95%, IR (neat/cm^{-1}) 3310, 2908, 2848, 1665, 1470; ^{1}H NMR (90 MHz; $CDCl_3$) 1.28 (8 H, s), 2.00-2.28 (6 H, m), 2.65 (2 H, t), 5.43 (1 H, t).

Representative Procedure for Oxidation of Homoallyl Alcohols 4a-c and 5a-c with $KMnO_4$-$CuSO_4.5H_2O$

$KMnO_4$ (8 g) and $CuSO_4.5H_2O$ (4 g) were ground to a fine powder in a mortar with pestle. To this fine powder water (0.40 mL) was added and mixed thoroughly. The slightly wet mixture was transferred to a reaction flask containing dichloromethane (10 mL). *tert*-Alcohol 4a (0.308 g, 2 mmol) in dichloromethane (2 mL) was added while stirring, followed by *tert*-butyl alcohol (1 mL). After stirring at room temperature for 4 h, the reaction mixture was filtered through a pad of Celite and washed thoroughly with dichloromethane. Removal of solvent and purification of the crude product by flash chromatography gave keto-lactone 6a (0.173 g, 46%), IR (neat/cm^{-1}) 1734, 1713; ^{1}H NMR (90 MHz; $CDCl_3$) 1.59 (6 H, s), 1.68-1.88 (4 H, m), 2.27 (2 H, t), 2.53 (2 H, t), 2.90 (2 H, s); ^{13}C NMR (22.6 MHz, $CDCl_3$) 24.8, 28.4, 35.9, 41.2, 51.6, 80.6, 175.0, 210.2; MS(*m/z*) 184 (M^+); HRMS Calcd for $C_{10}H_{16}O_3$ 184.1245, Found 184.1231, which was eluted first (petroleum ether-ethylacetate, 9:1) followed by epoxide **7a** (0.004 g, 1%), IR (neat/cm^{-1}) 3430, 2932, 2860; ^{1}H NMR (90 MHz; $CDCl_3$) 1.24 (3 H, s), 1.34 (3 H, s) 1.72 -2.50 (10 H, m), 2.78 (s, -OH), 3.04 (1 H, t, *J* 5); ^{13}C NMR (22.6 MHz; $CDCl_3$) 24.4, 29.2, 29.9, 30.8, 32.2, 45.6, 63.6, 64.0, 71.5; MS(*m/z*) 170 (M^+), 152 (M^+-18); HRMS Calcd for $C_{10}H_{18}O_2$ 170.1312, Found 170.1309.

Oxidation of Alcohol 4b. Oxidation of alcohol 4b (2 mmol) yielded keto-lactone **6b** (28%), IR (neat/cm^{-1}) 2932, 1728; ^{1}H NMR (90 MHz; $CDCl_3$) 1.58 (6 H, s), 2.24 -2.36 (2 H, m), 2.56 (2 H, t), 2.82 (2 H, s); ^{13}C NMR (22.6 MHz; $CDCl_3$) 20.8, 22.4, 24.9, 26.2, 35.5, 40.1, 51.7, 81.1, 171.9, 209.6; MS(*m/z*) 198 (M^+), 143, 83; HRMS Calcd for $C_{11}H_{18}O_3$ 198.1256, Found 198.1255, and epoxide **7b** (18%), IR (neat/cm^{-1}) 3412, 2914, 2848, 1443; ^{1}H NMR (90 MHz; $CDCl_3$) 1.22 (3 H, s), 1.38 (3 H, s), 1.48 (6 H, br s), 1.80 (2 H, s), 3.0 (1 H, t, *J* 3.6), 3.46 (s, -OH); ^{13}C NMR (22.6 MHz; $CDCl_3$) 24.4, 29.1, 29.7, 31.0, 31.3, 35.0, 48.0, 63.7, 64.2, 71.7; MS(*m/z*) 184 (M^+), 166 (M^+-18); HRMS Calcd for $C_{11}H_{20}O_2$ 184.1463, Found 184.1449.

Oxidation of Alcohol 4c. Alcohol 4c (2 mmol) yielded keto-lactone **6c** (5%), IR (neat/ cm^{-1}) 2920, 1735, 1715; ^{1}H NMR (90 MHz; $CDCl_3$) 1.32-1.50 (4 H, m), 1.52-1.86 (10 H, m), 2.20-2.58 (4 H, m), 2.82 (2 H, s); ^{13}C NMR (22.6 MHz; $CDCl_3$) 21.7, 22.5, 25.7, 27.1, 35.2, 44.7, 51.3, 81.8, 173.5, 210.6; MS(*m/z*) 212 (M^+), 157,83; HRMS Calcd for $C_{12}H_{20}O_3$ 212.1412, Found 212.1423, and epoxide **7c** (51%), IR (neat/cm^{-1}) 3430, 2908, 2854, 1464; ^{1}H NMR (90 MHz; $CDCl_3$) 1.22 (3 H, s), 1.38 (3 H, s), 1.48 (10 H, br s), 1.80 (4 H, s), 2.91-3.04(1 H, m), 3.48(s ,-OH); ^{13}C NMR (22.6 MHz; $CDCl_3$) 24.9, 25.6, 26.0, 26.7, 27.2, 30.1, 43.6, 62.3, 63.9, 71.3; MS(*m/z*) 180 (M^+-18), 137; HRMS Calcd for $C_{12}H_{20}O$ ($C_{12}H_{22}O_2$-H_2O) 180.1494, Found 180.1499.

Oxidation of Alcohol 5a. Oxidation of alcohol 5a (2 mmol) gave only keto-lactone **8a**. Yield, 32%, IR (neat/cm^{-1}) 1735, 1713; ^{1}H NMR (90 MHz; $CDCl_3$) 1.48-2.00 (4 H, m), 2.36 (4 H, t), 2.77 (2 H, t), 4.57 (2 H, t); ^{13}C NMR (22.6 MHz; $CDCl_3$) 22.1, 24.8, 35.3, 40.1, 43.7, 62.4, 173.6, 211.0; MS(*m/z*) 156 (M^+), 84, 55; HRMS Calcd for $C_8H_{12}O_3$ 156.0786, Found 156.0782,

Oxidation of Alcohol 5b. Alcohol 5b (2 mmol) produced keto-lactone **8b** as the only product. Yield, 30%, IR (neat/cm^{-1}) 2932, 1737, 1713; ^{1}H NMR (90 MHz; $CDCl_3$) 1.20-1.88 (6 H, m), 2.24-2.60 (4 H, m), 2.76 (2 H, t), 4.47 (2 H, t); ^{13}C NMR (22.6 MHz; $CDCl_3$) 21.9, 22.7, 24.9, 34.5, 39.4, 42.8, 61.3, 172.8, 211.4; MS(m/z) 170 (M^+), 98, 55; HRMS Calcd for $C_9H_{14}O_3$ 170.0943, Found 170.0947.

Oxidation of Alcohol 5c. Epoxide **9c** was obtained from alcohol **5c** (2 mmol) after oxidation. Yield, 15%, IR (neat/cm^{-1}) 3388, 2908, 1470; ^{1}H NMR (90 MHz; $CDCl_3$) 1.52 (8 H, br s), 1.72-2.32 (6 H, m), 2.88-3.00 (1 H, m), 3.76 (2 H, t); MS(m/z) 170 (M^+); HRMS Calcd for $C_{10}H_{18}O_2$ 170.1307, Found 170.1310.

Representative Procedure for Oxidation of Alcohols 4a-c and 5a-c with $KMnO_4$- Montmorillonite K-10

$KMnO_4$ (8 g) and montmorillonite K-10 (4 g) were ground to a fine powder in a mortar with pestle. To this fine powder water (0.40 mL) was added and mixed thoroughly. The slightly wet mixture was transferred to a reaction flask containing dichloromethane (10 mL). Alcohol **4a** (0.308 g, 2 mmol) in dichloromethane (2 mL) was added while stirring, followed by *tert*-butyl alcohol (1 mL). Stirring was continued at room temperature for 4 h. Reaction mixture was filtered through a pad of Celite and washed thoroughly with dichloromethane. Evaporation of solvent and purification of the crude product by flash chromatography (petroleum ether-ethyl acetate, 9:1) gave only the keto-lactone **6a** (0.191 g, 52%), found to be identical with the keto-lactone **6a** obtained earlier.

Oxidation of Alcohol 4b. Keto-lactone **6b** (45%) and epoxide **7b** (4%) were obtained as the oxidation products from the above alcohol **4b** (2 mmol).

Oxidation of Alcohol 4c. Keto-lactone **6c** (13%) and epoxide **7c** (22%) were obtained after the oxidation of the alcohol **4c** (2 mmol).

Oxidation of Alcohol 5a. Alcohol **5a** (2 mmol) produced keto-lactone **8a** in 35% yield.

Oxidation of Alcohol 5b. Alcohol **5b** (2 mmol) yielded keto-lactone **8b** in 29% yield.

Oxidation of Alcohol 5c. Epoxide **9c** (12%) was obtained from the alcohol **5c** (2 mmol) after the oxidation.

Oxidation of Epoxide 7a with $KMnO_4$-$CuSO_4.5H_2O$. Epoxide **7a** (0.5 mmol) was recovered unchanged after the oxidation (4 h).

Oxidation of Epoxide 7b with $KMnO_4$-$CuSO_4.5H_2O$. Under similar reaction conditions as above, epoxide 7b (0.5 mmol) was recovered unchanged after 4 h.

Preparation of Acetate 14. Acetate 14 was prepared from the *tert*-alcohol 4b (3 mmol) following the standard procedure.[20] Yield, 76%, IR (neat/cm^{-1}) 1730; ^{1}H NMR (90 MHz; $CDCl_3$) 1.40 (6 H, s), 1.60 (6 H, br s), 1.90 (3 H, s), 2.01-2.30 (4 H, m), 2.40 (2 H, s), 5.60 (1 H, t); MS(*m/z*) 210 (M$^+$), 168, 43, Anal Calcd for $C_{13}H_{22}O_2$, C, 74.24, H, 10.55; Found C, 74.20, H, 10.66.

Oxidation of Acetate 14 with $KMnO_4$-$CuSO_4$.$5H_2O$. Oxidation of acetate 14 (1 mmol) gave the following products after 3 h; ketol acetate 15 (31%), IR (neat/cm^{-1}) 1450, 1728, 1695; ^{1}H NMR (90 MHz; $CDCl_3$) 1.48 & 1.54 (6 H, 2 s), 1.92 (3 H, s), 4.08 (-OH), MS(*m/z*) 243 (M$^+$+1), 225, 183, Anal Calcd for $C_{13}H_{22}O_4$, C, 64.44, H, 9.16; Found C, 64.73, H, 9.23, and epoxide 16 (17%) IR (neat/cm^{-1}) 1730; ^{1}H NMR (90 MHz; $CDCl_3$) 1.48 & 1.52 (6 H, 2 s), 1.80-2.12 (12 H, m), 2.00 (3 H, s), 2.90 (1 H, t), MS(*m/z*) 227 (M$^+$+1), 211, 185, Anal Calcd for $C_{13}H_{22}O_3$, C, 68.99, H, 9.79; Found C, 69.13, H, 9.88.

Hydrolysis of Ketol Acetate 15. The above acetate 15 (0.073 g, 0.3 mmol) was taken in a reaction flask to which were added dry methanol (1 mL) and anhydrous potassium carbonate (0.07 g, 0.5 mmol). The reaction mixture was worked-up after stirring it at room temperature for 0.5 h by the addition of water (2 mL) and extracted with dichloromethane (3X3 mL). Drying over anhydrous $MgSO_4$ and removal of solvent yielded a crude product which was purified by flash chromatography (petroleum ether- ethylacetate, 98:2) to give the cyclic acetal 17 (0.05 g, 78 %), IR (neat/cm^{-1}) 3500, 1450, 1360, 1190; ^{1}H NMR (90 MHz; $CDCl_3$) 1.24 & 1.36 (6 H, 2 s), 1.40-2.04 (12 H, m), 3.28 (3 H, s), 3.94 (-OH), MS(*m/z*) 214 (M$^+$), 199, 182, Anal Calcd for $C_{12}H_{22}O_3$, C, 67.25, H, 10.35; Found C, 67.41, H, 10.47.

Oxidation of Cyclic Acetal 17 with $KMnO_4$-$CuSO_4$.$5H_2O$. Acetal 17 (0.2 mmol) yielded keto-lactone 6b (50%) which was found to be identical with the keto-lactone obtained earlier.

ACKNOWLEDGEMENT

The authors wish to thank CSIR, New Delhi for a SRF to JD.

REFERENCES

1. Nicolaou, K. C. *Tetrahedron*, **1977**, *33*, 683.
2. Back, T. G. *Tetrahedron*, **1977**, *33*, 3041.
3. a) Keller-Schierlein, W. *Fortschr. Chem. Org.Naturstoffe*, **1973**, *30*, 313. b) Celmer, W. D. *Pure Appl. Chem.*, **1971**, *28*, 413.
4. Posner, G. H.; Webb, K. S.; Ashirvatham, E.; Jew, S. -S.; Degl'Innocenti, A. *J. Am. Chem.Soc.*, **1988**, *110*, 4754.
5. a) Falbe, J.; Korte, F. *Chem. Ber.*, **1963**, *96*, 919. b) Borowitz, I. J.; Bandurco, V.; Heyman, M.; Rigby, R. D. G.; Ueng, S. -N. *J. Org. Chem.*, **1973**, *38*, 1234. c) Borowitz, I. J.; Williams, G. J.;Gross, L.; Beller, H.; Kurland, D.; Suciu, N.; Bandurco, V.; Rigby, R. D. G. *J. Org. Chem.*, **1972**, *37*, 581. d) Borowitz, I. J.; Williams, G. J.; Gross, L.; Rapp, R. *J. Org. Chem.*, **1968**, *33*, 2013. e) Borowitz, I. J.; Gonis, G.; Kelsey, R.; Rapp, R.; Williams, G. J. *J. Org. Chem.*, **1966**, *31*, 3032. f) Mahajan, J. R.; Ferreira, G. A. L.; Aranjo, H. C. *J. Chem. Soc., Chem. Commun.*, **1972**, 1078.
6. Baskaran, S.; Islam, I.; Raghavan, M.; Chandrasekaran, S. *Chem. Lett.*, **1987**, 1175.
7. a) Liotta, C. L.; Burgess, E. M.; Ray, C. C.;Black, E. D.; Fair, B. E. *ACS Symp. Ser.*, **1987**, 326; b) *Prep. Am. Chem. Soc., Div. Pet. Chem.* **1985**, *30*, 367.
8. Baskaran, S.; Das, J.; Chandrasekaran, S. *J. Org. Chem.*, **1989**, *54*, 5182.
9. Syamala, M. S.; Das, J.; Baskaran, S.; Chandrasekaran, S. *J. Org. Chem.*, **1992**, *57*, 1928.
10. Baskaran, S.; Islam, I.; Vanker, P. S.; Chandrasekaran, S. *J. Chem. Soc., Chem. Commun.*, **1990**, 1670.
11. Sharpless, K. B.; Teranishi, A. Y.; Bachvall, J. E. *J. Am. Chem. Soc.*, **1977**, *99*, 3120.
12. Santaniello, E.; Manzocchi, A. *Synthesis*, 1977, 698.
13. Charlesworth, E. H.; Campbell, H. J.; Stachiw, D. L. *Can. J. Chem.*, **1959**, *37*, 877.
14. Hugh, W. E.; Kon, G. A. R.; Mitchell, T. *J. Chem. Soc.*, **1929**, 1435.
15. Fieser, L. F.; Leffler, M. T. *et al*, *J. Am. Chem. Soc.*, **1948**, *70*, 3181.
16. Masamune, T.; Sato, S.; Abiko, A.; Ono, M.; Murai, A. *Bull. Chem. Soc. Jpn.*, **1980**, *53*, 2895.
17. Benkeser, R. A.; Arnold, Jr. C.; Lambert, R. F.; Thomas, O. H. *J. Am. Chem. Soc.*, **1955**, *77*, 6042.
18. Lillie, T. S.; Ronald, R. C. *J. Org. Chem.*, 1985, *50*, 5084.
19. Paquette, L. A.; Henzel, K. A. *J. Am. Chem. Soc.*, **1975**, *97*, 4649.
20. a) Steglich, W.; Hofle, G. *Angew. Chem., Int. Ed. Engl.*, **1969**, *8*, 981. b) Mueller, J.; Herz, J. E. *Steroids*, **1979**, *64*, 793.

(*Received in UK* 5 *July* 1994; *revised* 17 *August* 1994; *accepted* 19 *August* 1994)