Double Bond Migration on the 22(17→28)*abeo*-Lupane Skeleton

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Double bond migration on the 22(17→28)*abeo*-lupane skeleton was investigated using 28-*p*-toluenesulfonyloxylupane (4) and its 20(29)-ene derivative (7) as starting materials. In the case of 4, the double bond, formed between C-17 and C-28 after elimination of the *p*-toluenesulfonyloxy group followed by E-ring expansion, migrated to C-13 and C-18 under acidic conditions. In the case of 7, the double bond, formed after the elimination and the E-ring expansion, migrated in response to migration of the other double bond, 20(29)-ene, under acidic conditions. First, 20(29)-ene migrated to 19-ene (9), and then 17(28)-ene migrated to 13(18)-ene to form a conjugated 13(18),19-diene (10). Further migration proceeded to give an equilibrium mixture of 17α-*H*-11,13(18)-diene (11), 12,17-diene (12) and 17β-*H*-11,13(18)-diene (13) in a ratio of 3:3:5.

Keywords double bond migration; 22(17→28)*abeo*-lupane; ring expansion; 28-*p*-toluenesulfonyloxylupane; 28-*p*-toluenesulfonyloxylup-20(29)-ene; betulin

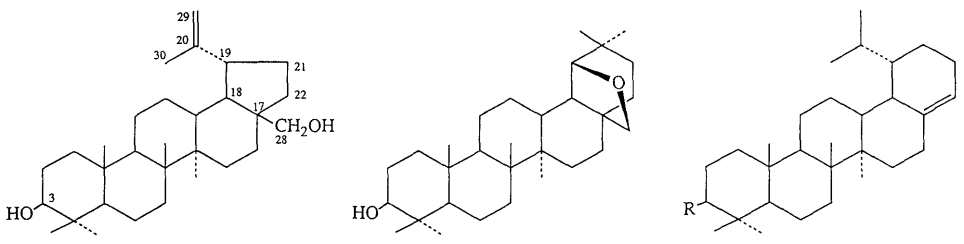
Betulin (**1**) is a naturally occurring triterpene, abundantly available mainly from birch bark.[1] Despite considerable effort, no notable chemical, industrial and pharmacological application has been established so far.

The chemical reactions of the functional groups, a primary and a secondary hydroxyl groups and a double bond, have been investigated thoroughly.[2] Two types of E-ring expansion have been reported. One is the acid-catalyzed biogenetic type reaction in which the bond from C-21 to C-19 shifts to C-20, affording a germanicane-type compound, allobetulin (**2**).[3] The other occurs through dehydration of the 28-hydroxyl group[4] or solvolysis of the 28-*p*-toluenesulfonyloxy group,[5] in which the bond from C-22 to C-17 shifts to C-28 affording 22(17→28)*abeo*-lupene derivatives (**3**).

As the compounds formed in the latter reaction have a new skeleton, further chemical modification might generate new pharmacological activities. The most important factor in designing chemical modification is the position of the double bonds. Therefore, the migration of the double bonds following the E-ring expansion was examined in detail. In this study, we prepared 28-*p*-toluenesulfonyloxylupane (**4**) and its 20(29)-ene derivative (**7**) as starting materials to avoid undesirable side reaction of the C-3 function and to make its easy to monitor the reaction by gas-liquid chromatography (GC).

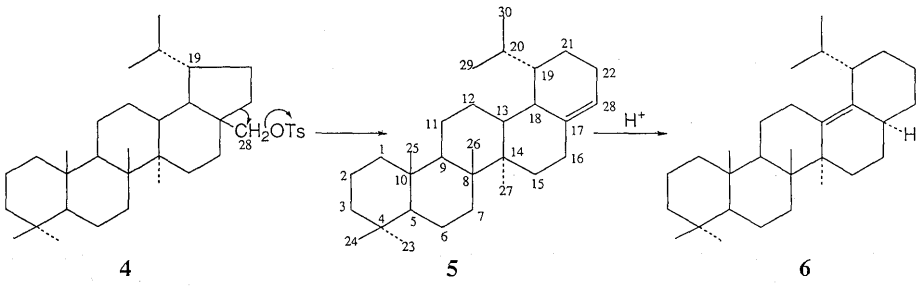
Reaction of 28-*p*-Toluenesulfonyloxylupane (4) The reaction of **4** in *N*,*N*-dimethylaniline[5] has been reported to yield a single product, 22(17→28)*abeo*-lup-17(28)-ene (**5**). Solvolysis of **4** in acetic acid containing 20% sodium acetate also gave a single product, **5**. The structure of **5** was confirmed by proton (^{1}H) and carbon-13 (^{13}C) nuclear magnetic resonance (NMR) spectroscopy (Table I and Experimental) and chemical conversion of **8** to **5** (Experimental). On the other hand, solvolysis in acetic acid gave **6** as the main product. The ^{13}C-NMR spectral data for **6** (Table I) showed the presence of a tetrasubstituted double bond in the molecule. In the ^{1}H-NMR spectrum of **6** in $CDCl_3$, proton signals of allylic methines at δ 2.02 (1H, ddd, J=12.0, 8.1, 4.4 Hz) and 2.36 (1H, ddd, J=10.3, 4.8, 2.2 Hz) and of an allylic methylene at δ 1.79 (1H, ddd, J=15.0, 5.5, 2.9 Hz) and 2.68 (1H, ddd, J=15.0, 4.8, 2.2 Hz) were observed. The signal at 2.36 is coupled with the signal of C_{20}-H at 1.90 (1H, d-septet, J=10.3, 6.6 Hz), and the signal at 2.68 showed the nuclear Overhauser effect (NOE) with the signals of the isopropyl group at 0.68 (3H, d, J=6.6 Hz), 0.91 (3H, d, J=6.6 Hz) and 1.90 (1H, d-septet, J=10.3, 6.6 Hz) in NOE correlation spectroscopy (NOESY). These data indicated the position of the double bond to be C-13 and C-18. Confirmation of the structure, including the stereochemistry at C-17 (17α-H), was obtained by chemical conversion of compound **11**, which will be mentioned later, into **6** by catalytic hydrogenation. Thus, the structure of **6** was determined as (17*S*)-22(17→28)*abeo*-lup-13(18)-ene. The result indicates that the double bond formed after the ring expansion migrated to a more stable position under acidic conditions.

Next, the reaction was examined in diethylene glycol, being monitored by thin-layer chromatography (TLC) and



1 2 3

Fig. 1



4 5 6

Fig. 2

TABLE I. ^{13}C-NMR Data in $CDCl_3$

C	5	6	8	9	10	11	13
1	40.4	40.5	40.4	40.4	40.5	39.6	39.7
2	18.6	18.7	18.6	18.6	18.7	18.5	18.4
3	42.1	42.1	42.1	42.1	42.1	42.3	42.3
4	33.3	33.3	33.3	33.3	33.2	33.3	33.3
5	56.4	56.4	56.4	56.5	56.4	56.1	56.0
6	18.7	18.8	18.7	18.7	18.7	18.7	18.7
7	34.5	34.9	34.2	34.5[a)]	35.8	32.5	32.6
8	41.1	41.2	41.1	41.3	41.1	40.5	40.6
9	50.1	50.8	50.5	51.1	50.8	54.2	54.0
10	37.5	37.6	37.4	37.5	37.7	37.1	37.0
11	20.8	21.6	21.2	21.2	21.4	125.5	125.3
12	25.8	25.3	26.6	25.8	26.2	125.4	125.0
13	43.3	133.0	46.1	42.3	131.6	132.1	134.0
14	42.6	43.9	42.3	42.3	43.1	41.6	41.7
15	34.1	26.2	33.8	34.1[a)]	26.2	24.0	26.3
16	33.3	25.7	32.8	32.4	25.3	25.4	28.1
17	141.8	33.1	141.7	143.6	40.1	32.9	33.7
18	40.3	135.3	41.0	44.8	135.8	140.3	139.3
19	38.5	45.5	43.9	130.7	136.0	44.4	42.8
20	28.1	27.3	150.8	123.4	120.5	26.8	27.6
21	21.2[a)]	30.4	27.7	27.3	32.7	30.4	29.0
22	21.0[a)]	22.3	23.5	23.9	28.5	22.0	20.5
23	33.4	33.4	33.4	33.4	33.5	33.2	33.2
24	21.5	21.7	21.6	21.6	21.7	21.2	21.2
25	16.2	16.4	16.3	16.3	16.3	17.9	17.9
26	15.9	17.9	15.9	16.0	18.6	16.6	17.1
27	14.9	20.8	14.9	15.0	21.2	19.6	20.3
28	117.4	34.7	118.3	117.3	34.9	36.2	37.6
29	20.7[b)]	21.0	108.9	19.9[b)]	18.7[a)]	21.0	21.3[a)]
30	22.1[b)]	21.0	22.4	21.0[b)]	21.6[a)]	21.0	21.7[a)]

a, b) Assignments may be interchanged in each column.

GC. Below 120 °C, the E-ring expansion did not occur. At about 125 °C, the reaction proceeded slowly, giving a mixture of **5** and **6** in a ratio of 5 : 1 after 15 h. The ratio of **6** increased in proportion to the reaction temperature. At boiling point (245 °C), the product was practically all **6**. In this reaction, *p*-toluenesulfonic acid, which was produced by the reaction is considered to catalyze the migration of the double bond. In fact, compound **5** in diethylene glycol without acid did not generate **6** even at boiling temperature. During these reactions, a putative intermediate, 22(17→28)*abeo*-lup-17-ene, was not detected by TLC or GC.

In conclusion, elimination of the 28-*p*-toluenesulfonyloxy group causes E-ring expansion and forms a double bond between C-17 and C-28. Under acidic conditions, the double bond migrates to between C-13 and C-18.

Reaction of 28-*p*-Toluenesulfonyloxylup-20(29)-ene (7) Solvolysis of **7** has been reported to cause E-ring expansion with a 17(28)-double bond, too. When the reaction was carried out in *N*,*N*-dimethylaniline, isomerization of the isopropenyl side chain to the isopropylidene chain was observed,[5] while in acetic acid containing sodium acetate, the isopropenyl side chain remained intact.[6] Under similar reaction conditions to the latter (acetic acid containing 20% sodium acetate), **7** gave a single product, **8**. The structure of **8** was confirmed by ^{1}H- and ^{13}C-NMR spectroscopic studies including ^{1}H–^{1}H shift correlation spectroscopy (COSY), ^{13}C–^{1}H COSY and long-range ^{13}C–^{1}H COSY.

On the other hand, the reaction in acetic acid caused migration of the double bonds after the E-ring expansion, giving many products. The reaction was monitored by GC (Fig. 3). In the first stage, the main product was compound **9**, which was replaced by four compounds, **10**, **11**, **12** and **13**, as the reaction proceeded. After 10 h, an equilibrium mixture was obtained which consisted mainly of **11**, **12** and **13** in a ratio of 3 : 3 : 5.

Compounds **9**—**13** were isolated by column chromatography on silica gel impregnated with silver nitrate and preparative TLC. They are isomers with the molecular formula $C_{30}H_{48}$. As the physical properties and spectral data were identical with those reported,[5] the structure of **9** was determined to be 17(28),19-diene.

Compound **10** has a conjugated diene system [UV $\lambda_{max}^{n\text{-hexane}}$ nm (log ε): 214 (4.43)] which consists of two tetrasubstituted double bonds [^{13}C-NMR ($CDCl_3$) δ: 136.0, 135.8, 131.6, 120.5]. As one of them was assigned as an isopropylidene double bond [^{1}H-NMR ($CDCl_3$) δ: 1.44 (3H, d, J=2.0 Hz), 1.64 (3H, s)] and the other was correlated to the 14α-methyl group in long-range ^{1}H–^{13}C COSY, the structure was determined as the 13(18),19-diene.

Compounds **11** and **13** are epimers having conjugated transoid dienes [UV $\lambda_{max}^{n\text{-hexane}}$ nm (log ε): 243 (4.45), 252 (4.52), 261 (4.33) for **11** and 245 (4.17), 252 (4.22), 262 (4.04) for **13**] consisting of *cis*-disubstituted and tetrasubstituted double bonds [^{1}H-NMR ($CDCl_3$) δ: 5.55 (1H, dd, J=10.5, 2.0 Hz) and 6.39 (1H, dd, J=10.5, 3.0 Hz) for **11** and 5.54 (1H, dd, J=10.5, 1.5 Hz) and 6.44 (1H, dd, J=10.5, 3.0 Hz) for **13**]. The UV data are identical with those of oleane-11,13(18)-diene[7] and **11** and **13** were identified as 11,13(18)-diene compounds with the help of ^{1}H–^{1}H COSY and long-range ^{1}H–^{13}C COSY (Fig. 5). Either **11** or **13** gave the same equilibrium mixture of **11**, **12** and **13** in boiling acetic acid containing 0.1% *p*-toluenesulfonic acid.

Compound **12** showed the presence of a conjugated

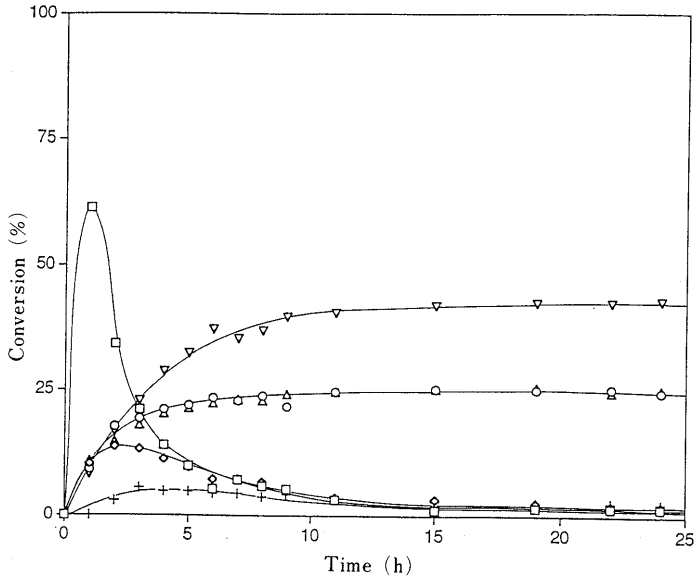


Fig. 3. Time Course of Each Product Formed from **7** in Boiling Acetic Acid

□, compound **9**; ◇, compound **10**; ○, compound **11**; △, compound **12**; ▽, compound **13**; +, not determined.

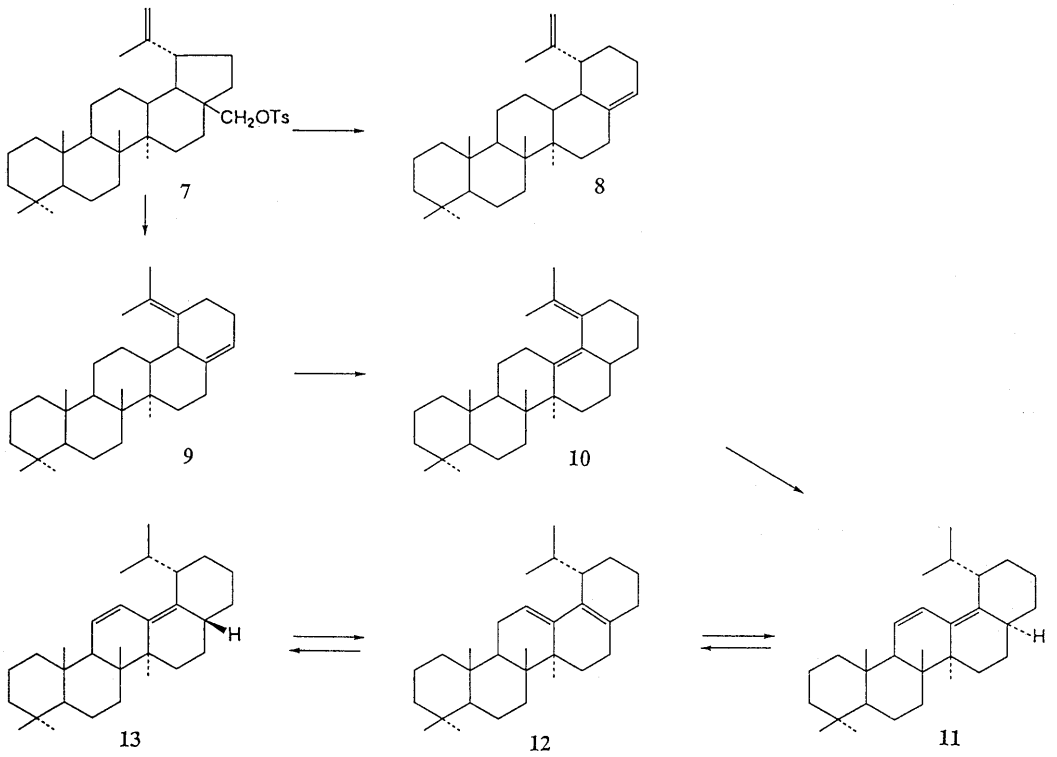
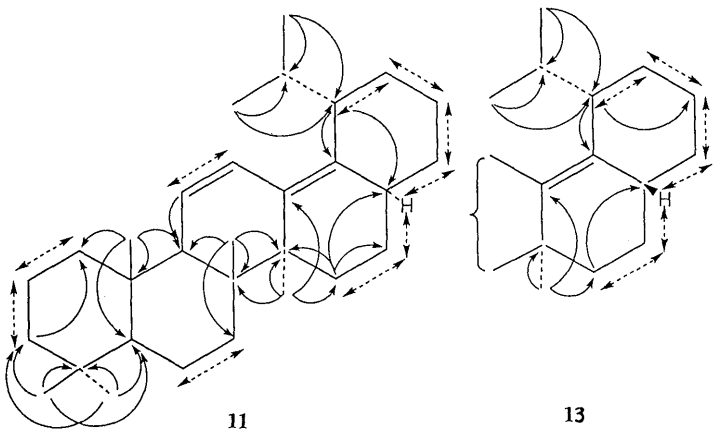


Fig. 4

diene [UV $\lambda_{max}^{n\text{-hexane}}$ nm ($\log\varepsilon$): 239 (4.14), 246 (4.19), 254 (4.04)] consisting of a trisubstituted double bond and a tetrasubstituted double bond [^{1}H-NMR ($CDCl_3$) δ: 5.53 (1H, br dd, J=5.3, 2.5 Hz); ^{13}C-NMR ($CDCl_3$) δ: 137.5 (C), 131.0 (C), 130.4 (C), 118.4 (CH)]. The UV data are the same as those of an ursa-12,17-diene derivative.[8] Considering the above-mentioned interconversion reaction, the structures were determined as the 12,17-diene for **12** and 17-epimers of the 11,13(18)-diene for **11** and **13**.

As each proton signal at C-12 of **11**, **12** and **13** showed NOE with the proton signal at C-19, they were considered to possess the same configuration at C-19, having the isopropyl side chain in a pseudoaxial position. On hydrogenation (H_2/Pt), compound **11** gave **6**. Therefore the configuration at C-19 was determined as *S* (19β-H). In NOESY, the proton signal at C-17 of **11** showed NOE with the methyl signals of the isopropyl side chain. Therefore, the configuration at C-17 was determined as *S* (17α-H) for **11**, and so *R* (17β-H) for **13**. This result was supported by ^{13}C-NMR data. In the case of the 17α-H form, C-15 and C-28 are in a γ-gauche relationship which is expected to induce upfield shifts of their ^{13}C signals.[9]



11 13

Fig. 5. ^{1}H–^{1}H COSY (←——→) and Long-Range ^{13}C–^{1}H COSY (^{1}H⌒^{13}C) Connections for Compounds **11** and **13**

In fact, the signals of C-15 and C-28 of **11** resonated at higher field than those of **13** by 2.3 and 1.4 ppm, respectively (Table I).

The reaction of **7** was also examined in diethylene glycol. Under reflux, **7** gave the equilibrium mixture of **11**,**12** and **13** after 1 h. At 125 °C, the reaction proceeded slowly and **9** was obtained as the main product after 2 h.

Experimental

Melting points were determined with a Yanagimoto micromelting apparatus and are uncorrected. Optical rotations were taken with a JASCO DIP-360 automatic polarimeter. The ^{1}H- and ^{13}C-NMR spectra were measured with a JEOL GSX-500 spectrometer. Ultraviolet (UV) spectra were recorded on a Hitachi 323 spectrometer and infrared (IR) spectra on a Shimadzu IR-460 spectrometer. Mass spectra (MS) were measured with Hitachi M-80A and JEOL SX-102 spectrometers. GC was run on a Shimadzu GC-8A gas chromatograph using a Dexil 300GC column (30 m × 0.25 mm i.d.) at 300 °C. Nitrogen was used as the carrier gas.

Preparation of 28-*p*-Toluenesulfonyloxylupane (4) and 28-*p*-Toluenesulfonyloxylup-20(29)-ene (7) The sulfonates **4** and **7** were prepared by tosylation of lupan-28-ol and 20(29)-lupen-28-ol.[5] **4**: colorless needles, mp 170—171 °C, $[\alpha]_D^{20}$ −11° (c=1.0, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 3450, 2950, 2860, 1600, 1460, 1380, 1360, 1180, 1170, 1100, 960, 840. UV λ_{max}^{MeOH} nm (log ε): 338 (3.90). EI-MS m/z: 582 $[M]^+$, 410, 231, 218, 191. HR-MS m/z: 582.4076. Calcd for $C_{37}H_{58}O_3S$: 582.4102. ^{1}H-NMR ($CDCl_3$) δ: 0.72 (3H, d, J=6.6 Hz), 0.76 (3H, s), 0.79 (3H, s), 0.80 (3H, s), 0.80 (3H, d, J=6.6 Hz), 0.84 (3H, s), 0.89 (3H, s), 2.46 (3H, s), 3.73 (1H, d, J=9.5 Hz), 4.04 (1H, d, J=9.5 Hz), 7.35 (2H, d, J=8.4 Hz), 7.80 (2H, d, J=8.4 Hz). ^{13}C-NMR ($CDCl_3$) δ: 144.6 (C), 132.9 (C), 129.8 (CH), 128.0 (CH), 69.5 (CH_2), 56.2 (CH), 49.9 (CH), 48.0 (CH), 46.9 (C), 44.4 (CH), 42.7 (C), 42.1 (CH_2), 40.9 (C), 40.2 (CH_2), 37.3 (C), 37.2 (C), 34.2 (CH_2), 34.1 (CH_2), 33.3 (CH_3), 33.2 (C), 29.4 (CH), 29.2 (CH_2), 26.7 (CH_2), 26.3 (CH_2), 22.8 (CH_3), 21.6 (CH_3), 21.3 (CH_2), 20.5 (CH_2), 18.6 (CH_2), 18.5 (CH_2), 16.0 (CH_3), 15.8 (CH_3), 14.8 (CH_3), 14.6 (CH_3). **7**: a white amorphous powder, $[\alpha]_D^{20}$ +50° (c=1.0, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 3050, 2940, 2880, 1640, 1595, 1460, 1390, 1365, 1190, 1175, 1100, 1020, 960. UV λ_{max}^{MeOH} nm (log ε): 232 (4.09). EI-MS m/z: 580 $[M]^+$, 408, 231, 216, 191. HR-MS m/z: 580.3949. Calcd for $C_{37}H_{56}O_3S$: 580.3947. ^{1}H-NMR ($CDCl_3$) δ: 0.75 (3H, s), 0.79 (6H, s), 0.83 (3H, s), 0. 91 (3H, s), 1.64 (3H, s), 2.46 (3H, s), 3.75 (1H, d, J=9.5 Hz), 4.06 (1H, dd, J= 9.5, 1.8 Hz), 4.56 (1H, dd, J=2.2, 1.5 Hz), 4.64 (1H, d, J=2.2 Hz), 7.35 (2H, d, J=8.0 Hz), 7.81 (2H, d, J=8.0 Hz). ^{13}C-NMR ($CDCl_3$) δ: 149.7 (C), 144.7 (C), 132.8 (C), 129.9 (CH), 128.1 (CH), 110.0 (CH_2), 69.4 (CH_2), 56.3 (CH), 50.3 (CH), 48.7 (CH), 47.6 (CH), 46.7 (C), 42.6 (C), 42.1 (CH_2), 40.9 (C), 40.3 (CH_2), 37.6 (CH), 37.4 (C), 34.1 (CH_2), 34.0 (CH_2), 33.3 (CH_3), 33.2 (C), 29.3 (CH_2), 29.1 (CH_2), 26.5 (CH_2), 25.1 (CH_2), 21.6 (CH_3), 21.5 (CH_3), 20.5 (CH_2), 19.0 (CH_3), 18.7 (CH_2), 18.5 (CH_2), 16.0 (CH_3), 15.8 (CH_3), 14.7 (CH_3).

***Reaction of* 4 *in* Acetic Acid Containing 20% Sodium Acetate** A solution of the *p*-toluenesulfonate **4** (30 mg) in acetic acid containing 20% sodium acetate (10 ml) was heated under reflux for 3 h. After cooling, the reaction mixture was poured into ice-water and extracted with ether. The organic layer was washed successively with water, 10% sodium carbonate solution and water, dried, and evaporated *in vacuo*. The residue was crystallized from $CHCl_3$–MeOH to afford **5** (15 mg). Colorless needles, mp 185—186 °C, $[\alpha]_D^{20}$ −49° (c=1.0, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 2950, 2880, 1460, 1445, 1380, 1370, 1360, 1345, 1195, 1080, 1040, 1010, 975, 800, 640. EI-MS m/z: 410 $[M]^+$, 395 $[M-CH_3]^+$, 367, 231, 191. HR-MS m/z: 410.3910. Calcd for $C_{30}H_{50}$: 410.3910. ^{1}H-NMR ($CDCl_3$) δ: 0.79 (3H, s), 0.83 (3H, s), 0.85 (3H, s), 0.87 (3H, d, J=6.7 Hz), 0.88 (3H, d, J=6.7 Hz), 0.95 (3H, s), 1.06 (3H, s), 5.32 (1H, d, J=4.3 Hz). ^{13}C-NMR ($CDCl_3$): Table I.

Reaction of 4 in Acetic Acid A solution of the 28-*p*-toluenesulfonate **4** (500 mg) in acetic acid (50 ml) was heated under reflux for 5 h. After cooling, the reaction mixture was poured into ice-water and extracted with ether. The extract was washed with water, 10% sodium carbonate solution and water, then dried and concentrated *in vacuo*. The residue was crystallized from acetone to afford **6** (220 mg). Colorless needles, mp 207—208 °C, $[\alpha]_D^{21}$ −92° (c=1.0, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 3000, 2930, 2850, 1460, 1440, 1380, 1360, 1210, 1160, 1115, 1080, 1030, 1000, 980. EI-MS m/z: 410 $[M]^+$, 395 $[M-CH_3]^+$, 367, 229, 218, 190. HR-MS m/z: 410.3900. Calcd for $C_{30}H_{50}$: 410.3910. ^{1}H-NMR ($CDCl_3$) δ: 0.68 (3H, d, J=6.6 Hz), 0.80 (3H, s), 0.86 (3H, s), 0.87 (3H, s), 0.91 (3H, s), 0.91 (3H, d, J=6.6 Hz), 1.13 (3H, s), 2.36 (1H, ddd, J=10.3, 4.8, 2.2 Hz), 2.68 (1H, ddd, J=15.0, 4.8, 2.2 Hz). ^{13}C-NMR ($CDCl_3$): Table I.

Reaction of 4 in Diethylene Glycol A solution of the 28-*p*-toluenesulfonate **4** (100 mg) in diethylene glycol (25 ml) was heated under reflux for 3 h. After cooling, the reaction mixture was diluted with water and extracted with ether. The extract was washed with water, dried, and concentrated *in vacuo*. The residue was crystallized from acetone to afford **6** (40 mg).

Reaction of 7 in Acetic Acid Containing 20% Sodium Acetate A solution of the 28-*p*-toluenesulfonate **7** (30 mg) in acetic acid containing 20% sodium acetate (10 ml) was heated under reflux for 3 h. After cooling, the reaction mixture was poured into ice-water and extracted with ether. The extract was washed successively with water, 10% sodium carbonate solution and water, then dried and concentrated *in vacuo*. The residue was crystallized from $CHCl_3$–MeOH to give **8** (13 mg). Colorless needles, mp 144—145 °C, $[\alpha]_D^{21}$ −26° (c=1.0, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 3070, 3000, 2930, 2880, 1640, 1445, 1380, 1370, 1040, 975, 885, 805. EI-MS m/z: 408 $[M]^+$, 393 $[M-CH_3]^+$, 231, 216, 191. HR-MS m/z: 408.3758. Calcd for $C_{30}H_{48}$: 408.3753. ^{1}H-NMR ($CDCl_3$) δ: 0.79 (3H, s), 0.83 (3H, s), 0.85 (3H, s), 0.95 (3H, s), 1.03 (3H, s), 1.77 (3H, s), 4.65 (1H, s), 4.73 (1H, s), 5.35 (1H, t, J=4 Hz). ^{13}C-NMR ($CDCl_3$): Table I.

Reaction of 7 in Acetic Acid i) A solution of the 28-*p*-toluenesulfonate **7** (1 g) in acetic acid (140 ml) was heated under reflux for 1 h. After cooling, the reaction mixture was poured into ice-water and extracted with $CHCl_3$. The extract was washed with 10% sodium carbonate solution and water, then dried and concentrated *in vacuo*. The residue was purified by chromatography on 20% $AgNO_3$-impregnated silica gel (*n*-hexane) followed by recrystallization (benzene–MeOH) to give **9** (180 mg) and **10** (39 mg). **9**: colorless needles, mp 230—231.5 °C, $[\alpha]_D^{27}$ −164° (c=0.5, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 2920, 1436, 1373, 1035, 855, 832,

803, 670. EI-MS *m/z*: 408 $[M]^+$, 231, 201, 191, 148, 135. HR-MS *m/z*: 408.3749. Calcd for $C_{30}H_{48}$: 408.3752. ^{1}H-NMR ($CDCl_3$) δ: 0.79 (3H, s), 0.82 (3H, s), 0.85 (3H, s), 0.96 (3H, s), 1.13 (3H, s), 1.64 (3H, d, J=1.5 Hz), 1.69 (3H, s), 2.90 (1H, d, J=11.4 Hz), 5.33 (1H, d, J=5.5 Hz). ^{13}C-NMR ($CDCl_3$): Table I. **10**: colorless needles, mp 248—249.5 °C, $[\alpha]_D^{28}$ −50° (c=0.52, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 2900, 2830, 1440, 1360, 1195, 1160, 1115. UV $\lambda_{max}^{n\text{-hexane}}$ nm ($\log\varepsilon$): 214 (4.43). EI-MS *m/z*: 408 $[M]^+$, 393 $[M-CH_3]^+$, 365, 203, 191, 145. HR-MS *m/z*: 408.3749. Calcd for $C_{30}H_{48}$: 408.3752. ^{1}H-NMR ($CDCl_3$) δ: 0.80 (3H, s), 0.866 (3H, s), 0.869 (3H, s), 1.14 (3H, s), 1.44 (3H, d, J=1.8 Hz), 1.64 (3H, s), 2.31 (1H, ddd, J=14.7, 5.1, 1.8 Hz), 2.64 (1H, dt, J=12.5, 3.3 Hz). ^{13}C-NMR ($CDCl_3$): Table I.

ii) A solution of the 28-*p*-toluenesulfonate **7** (1 g) in acetic acid (140 ml) was heated under reflux for 11 h. After cooling, the reaction mixture was poured into ice-water and extracted with $CHCl_3$. The extract was washed with 10% sodium carbonate solution and water, then dried and concentrated *in vacuo*. The residue was purified by chromatography on 20% $AgNO_3$-impregnated silica gel (*n*-hexane) and preparative TLC (petroleum ether) to give **11** (20 mg), **12** (26 mg) and **13** (111 mg). **11**: colorless needles, mp 212—214.5 °C, $[\alpha]_D^{20}$ −123° (c=0.4, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 2910, 2850, 1450, 1370, 1360, 1205, 620. EI-MS *m/z*: 408 $[M]^+$, 393 $[M-CH_3]^+$, 365, 269, 227, 187. HR-MS *m/z*: 408.3749. Calcd for $C_{30}H_{48}$: 408.3753. UV $\lambda_{max}^{n\text{-hexane}}$ nm ($\log\varepsilon$): 243 (4.45), 252 (4.52), 261 (4.33). ^{1}H-NMR ($CDCl_3$) δ: 0.74 (3H, d, J=6.6 Hz, H_3-30), 0.76 (3H, s, H_3-26), 0.81 (3H, s, H_3-24), 0.87 (3H, s, H_3-23), 0.90 (3H, s, H_3-25), 0.93 (3H, s, H_3-27), 0.93 (3H, d, J=6.6 Hz, H_3-29), 2.46 (1H, ddd, J=10.7, 4.3, 2.7 Hz, H-19), 5.55 (1H, dd, J=10.5, 2.0 Hz, H-11), 6.39 (1H, dd, J=10.5, 3.0 Hz, H-12). ^{13}C-NMR ($CDCl_3$): Table I. **12**: a white amorphous powder, $[\alpha]_D^{24}$ +66.8° (c=0.52, $CHCl_3$). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 2930, 1451, 1375, 1360, 1110, 1086. EI-MS *m/z*: 408 $[M]^+$, 393 $[M-CH_3]^+$, 365, 216, 173, 95. HR-MS *m/z*: 408.3747. Calcd for $C_{30}H_{48}$: 408.3753. UV $\lambda_{max}^{n\text{-hexane}}$ nm ($\log\varepsilon$): 239 (4.14), 246 (4.19), 254 (4.04). ^{1}H-NMR ($CDCl_3$) δ: 0.78 (3H, d, J=7.0 Hz), 0.83 (3H, s), 0.88 (6H, s), 0.88 (3H, d, J=7.0 Hz), 0.97 (3H, s), 1.00 (3H, s), 5.53 (1H, dd, J=5.5, 2.7 Hz). ^{13}C-NMR ($CDCl_3$) δ: 137.5 (C), 131.0 (C), 130.4 (C), 118.4 (CH), 56.5 (CH), 47.4 (CH), 42.0 (CH_2), 41.3 (C), 40.6 (CH_2), 39.1 (C), 37.2 (C), 36.7 (CH), 34.0 (CH_2), 33.5 (CH_3), 33.2 (C), 31.0 (CH_2), 30.1 (CH), 29.2 (CH_2), 27.7 (CH_2), 24.1 (CH_2), 23.5 (CH_2), 21.8 (CH_3), 21.7 (CH_3), 20.7 (CH_3), 19.9 (CH_3), 19.2 (CH_2), 18.7 (CH_2), 18.6 (CH_2), 17.1 (CH_3), 16.1 (CH_3). **13**: a white amorphous powder, $[\alpha]_D^{25}$ −6.6° (c=0.71, $CHCl_3$). IR ν_{max}^{KBr} cm^{-1}: 2910, 2860, 1608, 1459, 1380, 1362, 1205, 1060, 840, 775, 653. EI-MS *m/z*: 408 $[M]^+$, 393 $[M-CH_3]^+$, 365, 297, 269, 229, 203, 187, 145, 119, 95. HR-MS *m/z*: 408.3768. Calcd for $C_{30}H_{48}$: 408.3754. UV $\lambda_{max}^{n\text{-hexane}}$ nm ($\log\varepsilon$): 245 (4.17), 252 (4.22), 262 (4.04). ^{1}H-NMR ($CDCl_3$) δ: 0.74 (3H, d, J=6.7 Hz, H_3-30), 0.79 (3H, s, H_3-26), 0.81 (3H, s, H_3-24), 0.86 (3H, s, H_3-23), 0.90 (3H, s, H_3-25), 0.93 (3H, d, J=6.7 Hz, H_3-29), 0.95 (3H, s, H_3-27), 2.45 (1H, dt, J=10.0, 3.1 Hz, H_3-19), 5.54 (1H, dd, J=10.5, 1.5 Hz, H-11), 6.44 (1H, dd, J=10.5, 3.0 Hz, H-12). ^{13}C-NMR ($CDCl_3$): Table I.

Catalytic Hydrogenation of Compound 11 A solution of **11** (39 mg) in AcOEt (10 ml) and EtOH (5 ml) was stirred with PtO_2 (20 mg) under reflux for 6 h and at room temperature for 7 h in an atmosphere of hydrogen. Then the mixture was filtered, and the filtrate was concentrated *in vacuo*. The residue was purified by chromatography on 20% $AgNO_3$-impregnated silica gel (*n*-hexane) to afford **6** (7 mg) and **11** (26 mg).

References and Notes

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