Functionalized enamines XXVIII[1]. A facile synthesis of 6-methyl-19-norsteroids

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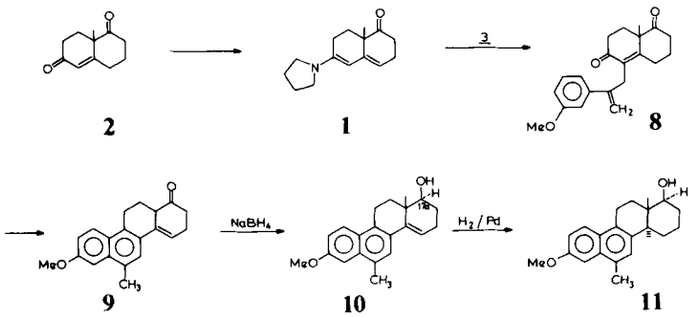
Abstract. Dienamines derived from 8a-methyl-1,6-dioxo-1,2,3,4,6,7,8,8a-octahydronaphthalene (**2**) and (+)(7a*S*)-7a-methyl-2,3,5,6,7,8-hexahydro-1,5(1*H*)-indandione (**12**) react with 3-bromo-2-(3-methoxyphenyl)propene (**3**) to give the corresponding 5- and 4-substituted alkylation products **8** and **14a**, respectively. **8** can be directly cyclized to 6-methyl-D-homoequilenin derivative **9** by heating with acid. While **14a** can be similarly converted into the corresponding equilenin methyl ether (**15a**), better yields in the cyclization step are achieved by initial reduction of the 5-ring ketone function and acetylation of the resulting alcohol. The latter sequence of reactions with **14a**, derived from **12**, gives optically active 17β-acetoxy-6-methylestra-1,3,5,7,9,14-haxaen-3-ol methyl ether (**15b**), which can serve as an central intermediate for optically active steroids.

The synthesis of 6-methyl-steroids and the corresponding 19-nor compounds[2] has received a great deal of attention in view of the demonstrated biological properties of some of the members of this class of steroidal hormones[3a-c]. In this laboratory, a strategy for the *de novo* synthesis of modified steroids has been developed, which involves the utility of dienamine intermediates derived from the *pro*-CD rings of the steroid skeleton[4a-d]. In this connection, the reaction of such dienamines (exemplified by **1**, Scheme I) with a variety of electrophiles has been examined in detail[5a,b], especially with respect to the mechanism, the stereochemistry and the factors affecting the site of electrophile attack of the dienamine. We now report a convenient general route to 6-methyl-19-norsteroids, including the synthesis of an optically active steroidal intermediate, based upon the dienamine medicated CD → ABCD scheme. Two recently reported syntheses of ring A aromatic steroids[6a,b], which made use of the CD → ABCD sequence, utilize reaction schemes which conceptually differ from ours in their chemical approach.



2 1 8 9 10 11

Scheme 1

The starting dienamine **1**[7] is readily prepared from the conveniently available bicyclic diketone **2**. A principal difficulty in using **2**, or many of its derivatives, as CD precursors, lies in the attachment of an arylethyl moiety at the desired carbon [*pro*-C(8)], of the bicyclic system, in practically useful yields[8a,b]. The results of investigations of the reaction of electrophiles with dienamines[9] suggested that a regiospecific alkylation of a dienamine such as **1**, with an appropriate arylalkyl halide, should provide a solution to the aforementioned problem. Especially relevant to this approach was the observed influence of the base moiety of the enamines or the dienamines upon the site of attack of the electrophilic reagent[4b]. Morpholine and piperdine (di)enamines were found to react with allylic halides to yield *N*-alkylated salts, which underwent a rapid [3,3]-sigmatropic rearrangement to *C*-alkylated products containing the "rearranged" allyl group[10a]. Pyrrolidine (di)enamines, on the other hand, underwent a direct attack at the β-carbon (N − $C_\alpha = C_\beta$) to form "normal" alkylated products[10a,b]. For the synthesis of 6-methyl steroids, the arylalkyl halide which was recognized as the suitable precursor of the AB ring system, is 3-bromo-2-(3-methoxyphenyl)propene (**3**), Scheme II). In view of the aforegone discussion on the reactivity of (di)enamines, the pyrrolidine system was chosen as the base component of the dienamine intermediate.

Bromide **3** was synthesized by bromination of 2-(3-methoxyphenyl)-propene (**4**)[12] with *N*-bromosuccinimide (NBS)[11].

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[1] Part XXVII. *H.P. Soetens* and *U.K. Pandit*, Heterocycles, in press.

[2] *V. Petrov*, Chem. Rev., **70**, 713 (1970).

[3] (a) *H. J. Ringold, E. Batres* and *G. Rosenkranz*, J. Org. Chem. **22**, 99 (1957); (b) *J. A. Campbell, J. C. Babcock* and *J. A. Hogg*, J. Am. Chem. Soc. **80**, 4717 (1958); (c) *J. C. Babcock, E. S. Gutsell, M. E. Herr, J. A. Hogg, J. C. Stucki, L. E. Barnes* and *W. E. Dulin*, J. Am. Chem. Soc. 2904 (1958).

[4] (a) *U. K. Pandit* and *H. Bieräugel*, Recl. Trav. Chim. Pays-Bas, **95**, 223 (1976); (b) *M. J. Pollmann, U. K. Pandit* and *H. O. Huisman*, Recl. Trav. Chim. Pays-Bas, **89**, 941 (1970); (c) *U. K. Pandit, M. J. M. Pollmann* and *H. O. Huisman*, J. Chem. Soc., Chem. Commun., 1969, 527; (d) *U. K. Pandit, K. de Jonge, K. Erhart* and *H. O. Huisman*, Recl. Trav. Chim. Pays-Bas, 1207 (1969).

[5] (a) *M. J. M. Pollmann, H. R. Reus, U. K. Pandit* and *H. O. Huisman*, Recl. Trav. Chim. Pays-Bas, **89**, 929 (1970); (b) *P. Houdewind*, "Electrofiele Substitutie van Dienaminen", Thesis, University of Amsterdam, 1973.

[6] (a) *N. Cohen, B. L. Banner, W. F. Eichel, D. L. Parrish, G. Sancy, J. M. Cassal, W. Meier* and *A. Fürst*, J. Org. Chem. **40**, 681 (1975); (b) *U. Eder, H. Gibian, G. Haffer, G. Neef, G. Sauer* and *R. Wichert*, Chem. Ber. **109**, 2948 (1976).

[7] *E. R. de Waard*, Thesis, University of Amsterdam, 1967, p. 49.

[8] (a) *G. H. Douglas, J. M. H. Graves, D. Hartley, G. A. Hughes, B. J. McLoughlin, J. Siddal* and *H. Smith*, J. Chem. Soc. 1963, 5072; (b) *D. J. Crispin, A. E. Vanstone* and *J. S. Whitehurst*, J. Chem. Soc. 1963, 5072, (c) 1970, 10.

[9] *U. K. Pandit, W. A. Zwart Voorspuij* and *P. Houdewind*, Tetrahedron Lett., 1997 (1972). Also see ref. 5a.

[10] (a) *P. Houdewind, U. K. Pandit, A. K. Bose, R. J. Brambilla* and *G. L. Trainor*, Heterocycles, **1**, 53 (1973); (b) *P. Houdewind* and *U. K. Pandit*, Tetrahedron Lett. 2359 (1974).

[11] *H. Pines, H. Alul* and *M. Kolobielski*, J. Org. Chem. **22**, 1113 (1957).

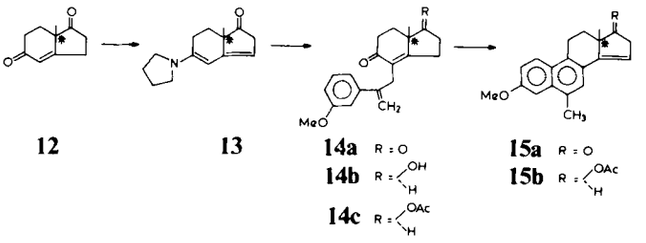
[12] *A. P. Uittewaal, F. L. Jonkers* and *A. v.d. Gen*, J. Org. Chem. **43**, 3306 (1978).

In the latter reaction, however, the formation of **3** is accompanied by substantial quantities of the isometric vinylic bromide **7**, the generation of which can be rationalized in terms of a previously suggested mechanism[11]. 2-(3-Methoxyphenyl)propene (**4**) was obtained *via* two routes. According to one procedure, starting with ester **5b**, prepared from the commercially available acid **5a**, condensation with excess of methylmagnesium iodide afforded alcohol **6**, which dehydrated by refluxing in with toluene in the presence of a catalytic quantity of iodine to olefin **4**. A second method, based upon the recently reported reaction of methylene ylid Ph_3PCH_2 with esters[12], yielded **4** from the starting ester **5b**, in one practical step (Scheme III).

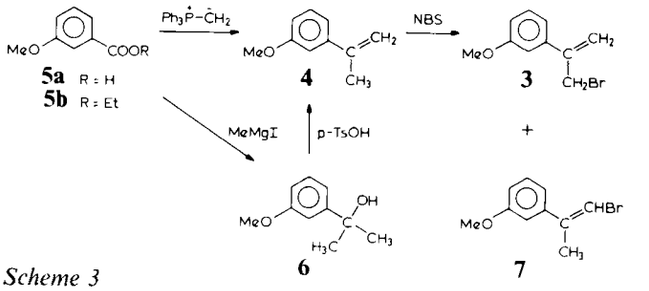
Reaction of dienamine **1** with allylic bromide **3**, in acetonitrile (0°, 3 days), gave a reaction mixture from which the seco-steroid **8** was isolated, after chromatography, in 42% yield. The structure of **8** was attested by its IR and NMR spectral data (*vide* experimental). When the seco-steroid **8** was refluxed in toluene in the presence of catalytic quantities of *p*-toluenesulfonic acid, the D-homosteroid **9** was obtained as a crystalline product (m.p. 139-140°). Characteristic in the NMR spectrum of **9** was the expected *C*(6)-aromatic methyl at δ 2.60 (s). Conventional reduction with sodium tetrahydridoborate led to **10**, which yielded the 3-methyl ether (**11**), m.p. 184–187° on catalytic hydrogenation. The stereochemistry of the hydroxyl function at C(17a) has been assigned by analogy with the known stereochemical course of sodium tetrahydridoborate reductions of the steroidal 17-ketones[13a,b]. Although catalytic hydrogenation of the 14,15-double bond in **10** can give rise to isomeric mixtures, the isolated product, however, corresponded to the C(14α)-system. The *trans* CD ring function was evidenced by the chemical shift of the 18-CH_3 group[14] (δ DMSO-d_6 0.61 S).

Having established that the "dienamine approach" could be successfully applied to the synthesis of the 19-norsteroidal (tetracyclic) intermediate in two steps (**1** → **8** → **9**), attention was directed to its application to the preparation of optically active steroids. With this objective, optically active **12** was synthesized by the procedure of *Hajos*[15] and converted into the required pyrrolidine dienamine **13**[16]. Reaction of **13** with allylic bromide **3**, under the previously described conditions, proceeded to give seco-steroid **14a** in good yield (70%). Cyclization of the latter compound was examined by a variety of procedures, using the corresponding racemic system. The best results were obtained when a toluene solution of **14a**, containing *p*-toluenesulfonic acid (30% w/w) was refluxed for 1.5 h. The yield of racemic 6-methyl-14,15-dehydroequilenin methyl ether (**15a**) in the last mentioned reaction was 9%. This low yield presumably reflects the high reactivity of the *pro*-C(16)-methylene group (flanked by a five-ring carbonyl and a double bond) towards condensation reactions under the acidic conditions. Consequently, it was decided to transform the carbonyl group into a less active functionality. Reduction of optically active **14a** with sodium tetrahydridoborate to **14b**, followed by acetylation, gave the corresponding acetate (**14c**) in good, overall yield. When the latter acetate was refluxed in benzene with *p*-toluenesulfonic acid (30% w/w) and molecular sieve 4A (4 h), the seco-steroid cyclized to yield optically active (**15b**) in 29% yield (m.p. 131–133°). Since reduction of the naphthalene ring of 3-methyl ether of equilenin and elaboration of the 17-position represent conventional transformations[17], compound **15b** constitutes a versatile intermediate for the synthesis of optically active 6-substituted 19-norsteroids.

It should be pointed out that, with the choice of appropriate base, in the dienamine and the allylic halide, the above-mentioned approach can be applied to the synthesis of 6- and 6,7-substituted ring A aromatic steroidal systems, which can serve as central intermediates for the preparation of a variety of modified steroids.



Scheme 2



Scheme 3

Experimental

Are melting points are uncorrected. Analyses were carried out by Mr. *H. Pieters* of the Microanalitical Department of this laboratory. IR, UV, CD and mass spectra were recorded on Unicam SP 200, Cary-14 Recording, Cary-60 and Varian Mat-71 or AEI MS-9 spectrometers, respectively. NMR spectra were measured on a Varian A.60 D, HA-100 or XL-100 spectrometer. Chemical shifts are reported relative to TMS.

Enamines **1** and **13** were prepared according to known procedures[7,16].

(+)(7aS)-7a-Methyl-2,3,5,6,7,8-hexahydro-1,5(1H)-indandione (**12**)

Diketone **12** was prepared according to the procedure described by *Hajos* and *Parrish*[15]. M.p. 61–65°, IR (KBr) 1738 cm^{-1}, 1660 cm^{-1}; UV (ethanol) 236 nm. (ε 10219); $[\pi]_D^{23}$ (ethanol) +339 (optical purity 92%); CD (ethanol) $[\theta]_{385}$ 0, $[\theta]_{351}$ +3347, $[\theta]_{325}$ +13388, $[\theta]_{308}$ +23988, $[\theta]_{267}$ 0, $[\theta]_{246}$ −71400, $[\theta]_{231}$ 0, $[\theta]_{220}$ +41279.

2-(3-Methoxyphenyl)-2-propanol (**6**)

A solution of methylmagnesium iodide (0.16 mol) was added dropwise to a solution of 14.00 g (0.078 mol) of ester **5** in 30 ml of dry ether, cooled under N_2 to +5°. After 15 min the mixture was allowed to come to room temperature and was stirred for 1 h. To this a solution of NH_4Cl was added, the ethereal layer separated, washed with water and dried over $MgSO_4$. Evaporation of the solvent and distillation of the residue afforded 11.0 g (61%) of **6**. B.p. 80–86°, 0.012 m. IR ($CHCl_3$) 3650 cm^{-1} (−OH), 3500 cm^{-1} (−OH), 1600 cm^{-1} and 1585 cm^{-1}; NMR ($CDCl_3$) δ 1.48 (2 × $-CH_3$), δ 3.72 ($-OCH_3$).

2-(3-Methoxyphenyl)propene (**4**)

To a solution of 8.7 g (0.052 mol) of alcohol **6** in 25 ml of dry toluene was added a catalytic quantity of I_2 and the mixture was refluxed for 3 h using a Dean Stark apparatus. Cooling the reaction mixture to room temperature, washing with a $Na_2S_2O_3$ solution, water, drying and evaporation of the solvent gave 8.9 g of an oil, which was distilled with a catalytic quantity of hydroquinone. B.p. 45–46°,

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[13] (a) *W. N. Speckamp, U. K. Pandit* and *H. O. Huisman*, Tetrahedron **21**, 2517 (1965); (b) *U. K. Pandit, W. N. Speckamp* and *H. O. Huisman*, Tetrahedron, **21**, 1767 (1965).

[14] *N. S. Bhacca* and *D. H. Williams*, "Application of NMR Spec- J. Am. Chem. Soc. **85**, 1134 (1963).

[15] *Z. G. Hajos* and *D. R. Parrish*, J. Org. Chem. **39**, 1615, 1612 (1974).

[16] *O. I. Fedorova, G. S. Grinenko* and *V. I. Maksimov*, J. Org. Chem. U.S.S.R., (English Trans.) **4**, 597 (1968).

[17] *E. J. Bailey, A. Gale, G. H. Phillips, P. T. Siddons* and *G. Smith*, J. Chem. Soc., Chem. Commun. 1253 (1967).

0.05 mm. Yield of **4** 6.1 g (78%). IR ($CHCl_3$) 1630, 1600 and 1580 cm^{-1}; NMR ($CDCl_3$) δ 2.12 ($-CH_3$, m), δ 3.77 ($-OCH_3$), δ 5.10 (vinyl H, m), δ 5.35 (vinyl H, m).

3-Bromo-2-(3-methoxyphenyl)propene (**3**)

To a solution of 9.8 g (0.066 mol) 2-(3-methoxyphenyl)propene (**4**), dissolved in 6 ml of dry CCl_4, were added 11.74 g of *m*-bromosuccinimide (NBS). The mixture was slowly heated; the reaction set in at 80°. After 10 min, 20 ml of *n*-pentane were added to the cooled mixture, and the precipitated succinimide was filtered off. After evaporation, the residue was distilled to yield 9.6 g of a mixture of the bromides **3** and **7** (3 : 1). IR ($CHCl_3$) (mixture) 1600 cm^{-1} and 1575 cm^{-1}. The isomers were characterized by their NMR ($CDCl_3$) spectra (**3**): δ 3.81 (s, $-OCH_3$), 4.30 (s, CH_2), 5.55 (m, $=CH_2$), (**7**): δ 2.21 (m, CH_3), 3.81 (s, OCH_3), 6.47 (m, vinylic H).

5-[2-(3-Methoxyphenyl)allyl]-8a-methyl-1,6-dioxo-1,2,3,4,6,7,8,8a-octahydronaphthalene (**8**)

To a solution of 2.3 g (0.01 mol) of enamine **1** in 20 ml of dry acetonitrile cooled to 0°, 0.01 mol of bromide **3** was added. After standing for 3 days at 0°C, some water and chloroform were added. Separation of the layers, washing the organic layer with water, drying and evaporation gave a residue which, after chromatographic separation on a silica gel column (eluent 6 : 1 $CHCl_3$/EtOAc), afforded 1.37 g (42%) of the seco-steroid **8**. IR ($CHCl_3$) 1705 cm^{-1}, 1660 cm^{-1}, 1600 cm^{-1} and 1580 cm^{-1}; NMR ($CDCl_3$) δ 1.42 ($-CH_3$), δ 3.86 ($-OCH_3$), δ 4.82 (vinyl H, m), δ 5.30 (vinyl H, m).

6-Methyl-14,15-didehydro-D-homoequilenin methyl ether (**9**)

A mixture of 1.0 g *seco*-steroid **8** (3.8 mmol), 0.3 g of *p*-toluenesulfonic acid and 60 ml of toluene was refluxed for 75 minutes using a Dean-Stark apparatus. After addition of EtOAc the organic layer was washed with water, Na_2CO_3 solution and dried over $MgSO_4$. Evaporation of the solvent and recrystallization of the residue from ethanol gave 0.384 g (41%) of steroid **9**. M.p. 139–140°; IR (KBr) 1705 cm^{-1} (C=O), 1615 cm^{-1} and 1600 cm^{-1}; NMR ($CDCl_3$) δ 1.22 ($C_{13}-CH_3$), δ 2.60 ($-CH_3$), δ 3.92 ($-OCH_3$), δ 6.34 (vinyl H, t, *J* 3.5 Hz), δ 7.45 (C(4)–H); Found: C, 82.48, H, 7.18, $C_{21}H_{22}O_2$ (306) requires: C, 82.35, H, 7.17.

6-Methyl-D-homoestra-1,3,5,7,9,14-hexaene-3,17aβ-diol 3-methyl ether (**10**)

To a solution of 306 mg (1 mmol) of ketone **9** in 5 ml of methanol were added 20 mg of sodium tetrahydridoborate and the mixture stirred for 4 days. After addition of some CH_3OH/HCl and evaporation of the solvent, an oil was obtained, which was chromatographed on a silica gel thick layer (eluent 9 : 1 $CHCl_3$/EtOAc). Yield 241 mg (78%) of **10** as crystals. M.p. 133–138°; IR (KBr) 3400 cm^{-1} (–OH), 1600 cm^{-1} and 1505 cm^{-1}; NMR ($CDCl_3$) δ 1.00 [C(19)–CH_3], δ 2.55 ($-CH_3$), δ 3.89 ($-OCH_3$), δ 6.20 (vinyl H, t, *J* 3.5 Hz).

6-Methyl-D-homoestra-1,3,5,7,9-pentaene-3,17aβ-diol 3-olmethyl ether (**11**)

A solution of 190 mg (0.6 mmol) of alcohol **10** in 5 ml of EtOH was hydrogenated over a Pd/C catalyst (5%, 20 mg) under 3 atm H_2. After 5 h the catalyst was filtered off and the solvent evaporated. Crystallization of the residue from ether gave 90 mg (47%) of **11** as colourless crystals. M.p. 184–187°; IR (KBr) 3470 cm^{-1} (–OH) and 1595 cm^{-1}; NMR (DMSO) δ 0.61 [C(19)–CH_3], δ 2.52 ($-CH_3$), δ 4.42 [C(18)–H, d, *J* 4.5 Hz]; Mass (70 eV) *m/e* 310 (M^+, 100%). Found: C, 81.07, H, 8.55. $C_{21}H_{26}O_2$(310) requires C, 81.25, H, 8.39.

4-[2-(3-Methoxyphenyl)allyl]-7a-methyl-2,3,5,6,7,8-hexahydro-1,5(1H)-indandione (**14a**)

To a solution of 0.55 g (2.5 mmol) of enamine **13** in 6 ml of dry acetonitrile, 2.5 mmol of bromide **3** was added and heated at 60° for 4 h. After evaporation of the solvent the residue was dissolved in THF and some 10% of HCl was added. Evaporation of the THF, addition of $CHCl_3$, washing with $NaHCO_3$ solution, drying and evaporation gave a residue which, after separation on silica gel (eluent 9 : 1 $CHCl_3$/EtOAc), afforded 541 mg (70%) of **14a**. IR ($CHCl_3$) 1740 cm^{-1}, 1660 cm^{-1}, 1600 and 1580 cm^{-1}; NMR ($CDCl_3$) δ 1.20 ($-CH_3$), δ 3.78 ($-OCH_3$), δ 4.87 (vinyl H, m), δ 5.23 (vinyl H, m).

6-Methyl-14,15-didehydroequilenin methyl ether (**15a**)

This steroid was prepared according to the procedure described for the D-homosteroid **9**. The product was chromatographed (silica, eluent $CHCl_3$). Yield 9.4%. M.p. 160–166°; IR (KBr) 1730 cm^{-1} (C=O) and 1600 cm^{-1}; NMR ($CDCl_3$, multiscan) δ 1.22 [C(18)–CH_3], δ 2.71 ($-CH_3$), δ 6.31 (vinyl H), δ 7.55 [C(4)–H]; Mass *m/e* 292 (M^+, 100%).

1-Hydroxy-4-[2-(3-methoxyphenyl)allyl]-7a-methyl-2,3,5,6,7,8-hexahydro-5(1H)-indanone (**14b**)

To a cooled solution (3°) of 0.310 g (1 mmol) of ketone **14a**, in 7 ml of ethanol, 30 mg of sodium tetrahydridoborate was added, and the mixture was allowed to come to 18°. After cooling, 0.3 ml of CH_3COOH was added and the solvents evaporated. Upon addition of chloroform to the residue, separation of the layers, washing with $NaHCO_3$ solution, drying and evaporation of the solvent, 298 mg (98%) of alcohol **14b** was obtained. IR ($CHCl_3$) 3680 cm^{-1} (–OH), 3500 cm^{-1} (–OH), 1665 cm^{-1} C(=O), 1600 cm^{-1} and 1580 cm^{-1}; NMR ($CDCl_3$) δ 1.07 ($-CH_3$), δ 3.78 ($-OCH_3$), δ 4.75 (vinyl H, dd), δ 5.18 (vinyl H, dd); UV (ethanol) 211 nm (ε 23300), 244 nm (ε 15000); $[\pi]^{20}_{577}$ (ethanol) +13, CD (ethanol) $[\theta]_{383}$ 0, $[\theta]_{381}$ +1525, $[\theta]_{269}$ +610, $[\theta]_{330}$ +6775, $[\theta]_{285}$ 0, $[\theta]_{247}$ −27790, $[\theta]_{224}$ 0, $[\theta]_{218}$ +8402.

1-Acetoxy-4-[2-(3-methoxyphenyl)allyl]-7a-methyl-2,3,5,6,7,8-hexahydro-5(1H)-indanone (**14c**)

A mixture of 196 mg (0.65 mmol) of alcohol **14b**, 0.7 ml of acetic anhydride and 1 ml of pyridine was stirred for 4 h. After addition of water, extraction with ethyl acetate, washing the organic layer with water, 2% HCl, $NaHCO_3$ solution, drying and evaporation, 207 mg (94%) of acetate **14c** were isolated. IR ($CHCl_3$) 1735 cm^{-1} (C=O), 1660 cm^{-1} (C=C), 1600 cm^{-1} and 1580 cm^{-1}; NMR ($CDCl_3$) δ 1.12 ($-CH_3$), δ 2.05 ($CH_3-C=O$), δ 3.79 ($-OCH_3$), δ 4.78 (C(8)–H, m), δ 5.20 (vinyl H, m).

(−)-(13S,17S)-17β-Acetoxy-6-methylestra-1,3,5,7,9,14-hexaen-3-olmethyl ether (**15b**)

A mixture of 117 mg (0.33 mmol) of acetate **14c**, 28 mg of *p*-toluenesulfonic acid, 200 mg of molecular sieves (4A) and 5 ml of dry benzene was refluxed for 8 h. The molecular sieves were filtered off and, after concentration of the reaction mixture in a vacuum, steroid **15b** (32.5 mg, 29%) was isolated by thin-layer chromatography (silica gel, eluent 9 : 1 $CHCl_3$/EtOAc). M.p. 131–133°, $[\alpha]^{20}_{577}$ ($CHCl_3$) −81, IR ($CHCl_3$) 1740 cm^{-1} (C=O); NMR ($CDCl_3$, multiscan), δ 1.05 [C(13)–CH_3], δ 2.13 (CH_3CO), δ 2.62 [C(6)–CH_3], δ 3.98 ($-OCH_3$), δ 5.19 [C(17)–H, t, *J* 4 Hz], δ 5.59 (vinyl H, t, *J* 1 Hz); UV (ethanol) 252 nm, (ε 35800), 258 nm (ε 49700), 268 nm (ε 52100), 288 nm (ε 12000), 299 nm (ε 15550), 312 nm (ε 14050), 336 nm (ε 1800), 353 nm (ε 1190); Mass *m/e* 336 (M^+, 16%).