A Simple Determination Method of the Absolute Configuration of 1-Arylethanthiols by an Intramolecular CH/π Shielding Effect in ^{1}H-NMR of Diastereomeric Thiol Esters

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A simple method for the determination of the absolute configuration of 1-arylethanthiols was achieved by the observation of an intramolecular CH/π shielding effect in ^{1}H-NMR of the corresponding thiol esters. (*S*)-Isomer of the diastereomers always shows remarkable shielding effect.

Key words thiol; absolute configuration; ^{1}H-NMR; diastereomer

We have already reported that a remarkable intramolecular CH/π shielding effect based on the CH/π interaction[1—5] could be used as a convenient determination method of the absolute configurations of 2-arylcyclohexanols as shown in Fig. 1.[6] A step further, we have clarified that this methodology was also applicable to various acyclic 1-aryl-1-alkylalcohols.[7]

Now, we have found that this methodology is a convenient technique for the determination of absolute configurations of various arylthiols as well. In this note, we wish to report a simple method of the determination of absolute configuration of chiral thiols having aryl function.

Thus far, there have been a few reports regarding the determination of absolute configuration of chiral thiols.[8,9] These methods using the ^{1}H-NMR measurement of the diastereomeric thiol esters are excellent in techniques, but the observation of the difference in the chemical shift values of ^{1}H-NMR between both the corresponding diastereomeric derivatives is necessary. This might be somewhat disadvantageous in the case that the available amount of the specimen is limited. Under these circumstances, if our determination method[6,7] could be applied to various chiral arylthiols as well as arylalcohols, the technique would be a useful tool since a remarkable difference in the degree of shielding effects between both diastereomers can be expected. Therefore, we examined the possibility of ^{1}H-NMR determination of the absolute configurations in the case of arylthiols by applying this method. The diastereomers (**3**, **4**) were easily obtained from the reaction of various (±)-1-arylethanthiols **1**[10—15] and acid chloride (**2**)[16] of 3β-acetoxyetienic acid. As expected, the chemical shift values in ^{1}H-NMR of the β-Me at the 18 position (C18-CH_3) on the steroid ring were apparently different between the diastereomers (Table 1, entries 1—5). One always appeared near δ 0.56 ppm, while the other always appeared near δ 0.69 ppm.

To clarify which diastereomer shows the shielding effect by the aromatic ring, we used the compound **1a** (27% *ee*) having the known absolute configuration.[11] As a result, we found that the diastereomer showing the shielding effect was derived from (*S*)-thiol (Chart 1).

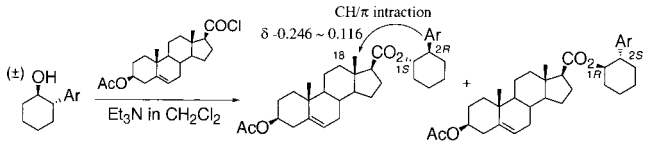

Fig. 1. Intramolecular CH/π Intraction

It is noteworthy that the C18-CH_3 signal appeared in the extremely distinct position between the (*S*)-isomer and (*R*)-isomer and each signal is accommodated in narrow range despite of use of various kinds of aromatic moieties. Namely when the stereochemistry of the thiol is (*S*), the chemical shift value of the signal of C18-CH_3 on the steroid ring ranged in the field from δ 0.54 to δ 0.58. On the other hand, when the stereochemistry of the thiol is (*R*), the chemical shift value of the signal of C18-CH_3 on the steroid ring ranged in the field from δ 0.69 to δ 0.71 (Table 1, entries 1—5). These results suggest that this methodology would be a highly general method for determining the absolute configuration of various analogues. In addition, a similar high field shift is also observed in the case of 1-benzylethanthiol (**1f**) (Table 1, entry 6).

The observed remarkable difference in the chemical shift values between the diastereomers suggested that our determination method for the chiral 1-arylethanthiols does not require to prepare both diastereomeric derivatives. Hence, we propose to determine the stereochemistry of 1-arylethanthiols in the following rules.

1) The stereochemistry of the thiol is (*S*), when the chemical shift value of the signal of 18β-Me on the steroid ring exists in higher field than δ 0.58.
2) The stereochemistry of the thiol is (*R*), when the chemical shift value of the signal of 18β-Me on the steroid ring exists in lower field than δ 0.69.

We believe that the presented determination technique of the absolute configurations for 1-arylethanthiols would be widely used in the field of dealing with chiral thiols.[17]

Experimental

Melting points are taken with a micro hot-stage apparatus (Yanagimoto) and are uncorrected. Infrared (IR) absorption spectra were recorded with a SHIMADZU FTIR-8400 spectrometer as a KBr pellet. ^{1}H- and ^{13}C-NMR spectra were measured on a JEOL JNM-EX270 or a JEOL JNM-AL300 spectrometers with $SiMe_4$ as the internal standard in $CDCl_3$. Mass spectra (MS) were determined on a JEOL JMS-AMII50 or a JEOL JMS-600 mass spectrometer. Specific rotations were measured by JASCO P-1020 polarimeter. Kanto Chemical Silica Gel 60N (spherical, neutral) and Fuji Silysia Chemical silica gel BW-300 were used for flash column chromatography respectively. The known 1-arylethanethiols[10—15] and acid chloride (**2**)[16] of 3β-acetoxyetienic acid were prepared by the reported method.

1-Phenylethanethiol[10] (**1a**): Colorless oil; ^{1}H-NMR (270 MHz, $CDCl_3$) δ:

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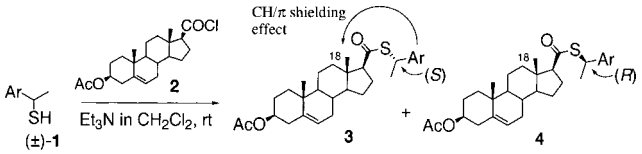
Table 1. ^{1}H-NMR Spectroscopic Determination of the Absolute Configuration of 1-Arylethanthiols Using CH/π Shielding Effect



Entry	Ar	Chemical shift of protons on C18-CH_3 in **3** or **4** [δ (ppm)]$^{a)}$	Predicted configuration of resolved **1**	Yield (%)$^{b)}$
1	Ph: **1a**	0.57	*S*$^{c)}$	93
		0.69	*R*	
2	4-Methoxy: **1b**	0.58	*S*	84
		0.69	*R*	
3	4-Chlorophenyl: **1c**	0.54	*S*	77
		0.68	*R*	
4	2-Naphthyl: **1d**	0.57	*S*	61
		0.71	*R*	
5	2-Pyridyl: **1e**	0.56	*S*	34
		0.69	*R*	
6	Bn: **1f**	0.55	*S*	68
		0.66	*R*	

a) 25 °C in $CDCl_3$. *b*) Isolated yields of a mixture of diastereomers by column chromatography. *c*) The configuration was confirmed by use of a substrate with known absolute configuration.

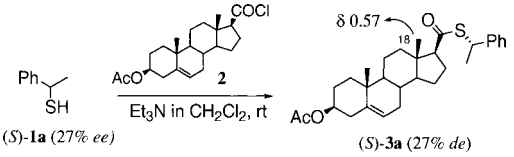


Chart 1. Determination of the Absolute Configuration of (*S*)-**3a**

1.67 (3H, d, *J*=6.9 Hz), 1.99 (1H, d, *J*=5.1 Hz), 4.23 (1H, dq, *J*=6.9, 5.1 Hz), 7.19—7.39 (5H, m). IR (KBr) cm^{-1}: 2563. MS *m/z*: 138 (M^+), 104.

(−)-(*S*)-1-Phenylethanethiol[11] [(*S*)-**1a**]: Colorless oil; $[\alpha]_D^{21}=-22.8°$ (1.30, $CHCl_3$); 27% *ee* [The *ee* was determined by the comparison of the optical rotations with literature].

1-(4-Methoxyphenyl)ethyl Thioacetate: Colorless oil; ^{1}H-NMR (270 MHz, $CDCl_3$) δ: 1.64 (3H, d, *J*=7.3 Hz), 2.29 (3H, s), 3.79 (3H, s), 4.71 (1H, q, *J*=7.3 Hz), 6.84 (2H, d, *J*=8.6 Hz), 7.25 (2H, d, *J*=8.6 Hz). ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 22.3, 30.4, 42.5, 55.3, 113.9, 128.2, 134.6, 158.7, 195.3. IR (KBr) cm^{-1}: 1686. EI-MS *m/z*: 210.0715 (Calcd for $C_{11}H_{14}O_2S$: 210.0714). MS *m/z*: 210 (M^+), 135.

1-(4-Methoxyphenyl)ethanethiol[12] (**1b**): Colorless oil. ^{1}H-NMR (270 MHz, $CDCl_3$) δ: 1.65 (3H, d, *J*=6.2 Hz), 1.97 (1H, d, *J*=6.2 Hz), 3.8 (3H, s), 4.22 (1H, m, *J*=6.2 Hz), 6.85 (2H, d, *J*=8.7 Hz), 7.29 (2H, d, *J*=8.7 Hz). ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 26.3, 38.2, 55.3, 113.9, 127.4, 137.9, 158.6. IR (KBr) cm^{-1}: 2561. EI-MS *m/z*: 168.0588 (Calcd for $C_9H_{12}OS$: 168.0609). MS *m/z*: 168 (M^+), 135.

1-(4-Chlorophenyl)ethyl Thioacetate: Colorless oil. ^{1}H-NMR (270 MHz, $CDCl_3$) δ: 1.62 (3H, d, *J*=7.2 Hz), 2.29 (3H, s), 4.70 (1H, q, *J*=7.2 Hz), 7.27 (4H, m). ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 21.9, 30.4, 42.2, 128.6, 128.7, 133.0, 141.3, 194.8. IR (KBr) cm^{-1}: 1693. EI-MS *m/z*: 214.0229 (Calcd for $C_{10}H_{11}OSCl$: 214.0219). MS *m/z*: 216 (M^++2), 214 (M^+), 139.

1-(4-Chlorophenyl)ethanethiol[12] (**1c**): Colorless oil. ^{1}H-NMR (270 MHz, $CDCl_3$) δ: 1.65 (3H, d, *J*=7.0 Hz), 1.98 (1H, d, *J*=5.1 Hz), 4.20 (1H, dq, *J*=7.0, 5.1 Hz), 7.27—7.32 (4H, m). ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 26.0, 38.0, 127.8, 128.7, 132.7, 144.3. IR (KBr) cm^{-1}: 2565. EI-MS *m/z*: 172.0127 (Calcd for C_8H_9SCl: 172.0113). MS *m/z*: 174 (M^++2), 172 (M^+), 139.

1-Naphthalen-2-yl-ethyl Thioacetate: Coorless oil. ^{1}H-NMR (270 MHz, $CDCl_3$) δ: 1.75 (3H, d, *J*=7.3 Hz), 2.31 (3H, s), 4.92 (1H, q, *J*=7.3 Hz), 7.42—7.48 (3H, m), 7.78—7.81 (4H, m). ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 22.0, 30.5, 43.1, 125.5, 125.6, 125.9, 126.2, 127.6, 127.8, 128.4, 132.6, 133.2, 139.9, 195.0. IR (KBr) cm^{-1}: 1688. EI-MS *m/z*: 230.0760 (Calcd for $C_{14}H_{14}OS$: 230.0765). MS *m/z*: 230 (M^+), 155.

1-Naphthalen-2-yl-ethanethiol[13] (**1d**): Colorless oil. ^{1}H-NMR (270 MHz, $CDCl_3$) δ: 1.76 (3H, d, *J*=6.9 Hz), 2.04 (1H, d, *J*=5.3 Hz), 4.33 (1H, m, *J*=6.4 Hz), 7.46 (1H, t, *J*=3.7 Hz), 7.47 (1H, t, *J*=3.8 Hz), 7.54 (1H, dd, *J*=8.7, 1.7 Hz), 7.75 (1H, m), 7.83—7.89 (3H, m). IR (KBr) cm^{-1}: 2563. MS *m/z*: 188 (M^+), 155.

1-Pyridin-2-yl-ethanethiol[14] (**1e**): Light yellow oil. ^{1}H-NMR (270 MHz, $CDCl_3$) δ: 1.73 (3H, d, *J*=6.8 Hz), 2.19 (1H, d, *J*=6.8 Hz), 4.25 (1H, m, *J*=6.8 Hz), 7.15 (1H, ddd, *J*=7.6, 4.9, 1.1 Hz), 7.33 (1H, d, *J*=7.7 Hz), 7.65 (1H, td, *J*=7.7, 1.8 Hz), 8.55 (1H, d, *J*=4.9 Hz); IR (KBr) cm^{-1}: 2515. MS *m/z*: 139 (M^+), 106.

1-Phenylpropan-2-thiol[15] (**1f**): Colorless oil. ^{1}H-NMR (270 MHz, $CDCl_3$) δ: 1.34 (3H, d, *J*=6.8 Hz), 1.56 (1H, d, *J*=5.6 Hz), 2.82 (1H, d, A part of AB, J_{AB}=13.4 Hz, *J*=7.5 Hz), 2.87 (1H, d, B part of AB, J_{AB}=13.4 Hz, *J*=6.7 Hz), 3.23 (1H, 7, *J*=6.6 Hz), 7.17—7.34 (5H, m). IR (KBr) cm^{-1}: 2567. MS *m/z*: 152 (M^+), 92.

A Typical Procedure of Thioesterification of Thiols 1 To a solution of 3β-acetoxy-5-etienic acid chloride (**2**, 687 mg, 1.8 mmol) in dry CH_2Cl_2 (3 ml) was added slowly triethylamine (202 μl, 1.45 mmol) and the solution of 1-phenylethanthiol (167 mg, 1.2 mmol) in dry CH_2Cl_2 (1 ml) at 0 °C . After an additional amount of solvent (6 ml) was admitted, the reaction mixture was stirred at room temperature for 22 h. Then, **2** (229 mg, 0.5 mmol) was added again and the reaction mixture was continued to stir for 22.5 h. The reaction mixture was washed with dist. H_2O, dried over Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by column chromatography on silica gel (eluent : hexane/AcOEt=10/1) to give 3β-acetoxy-10,13-dimethyl-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1*H*-cyclopenta[*a*]phenanthrene-17-carboxylic acid 1-phenylethyl thioester (**3a**, **4a**) (541 mg, 93% yield) as a diastereomeric mixture.

3β-Acetoxy-10,13-dimethyl-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1*H*-cyclopenta[*a*]phenanthrene-17-carboxylic Acid 1-Phenylethyl Thioester (**3a**, **4a**): White solid. mp 90—92 °C. IR (KBr) cm^{-1}: 1732, 1630. FAB-MS *m/z*: 481.2779 (Calcd for $C_{30}H_{41}O_3S$: 481.2781). MS *m/z*: 481 (M^++H), 154.

(*S*)-**3a**: ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.57 (3H, s), 0.93—2.33 (19H, m), 0.99 (3H, s), 1.64 (3H, d, *J*=7.0 Hz), 2.03 (3H, s), 2.53 (1H, t, *J*=9.2 Hz), 4.60 (1H, m), 4.75 (1H, q, *J*=7.0 Hz), 5.36 (1H, m), 7.20—7.36 (5H, m).

(*R*)-**4a**: ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.69 (3H, s), 0.93—2.33 (19H, m), 1.02 (3H, s), 1.65 (3H, d, *J*=7.2 Hz), 2.04 (3H, s), 2.53 (1H, t, *J*=9.2 Hz), 4.60 (1H, m), 4.76 (1H, q, *J*=7.2 Hz), 5.36 (1H, m), 7.20—7.36 (5H, m).

3β-Acetoxy-10,13-dimethyl-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1*H*-cyclopenta[*a*]phenanthrene-17-carboxylic Acid 1-(4-Methoxyphenyl)ethyl Thioester (**3b**, **4b**): White solid. mp 122.5—125 °C. IR (KBr) cm^{-1}: 1732, 1682. FAB-MS *m/z*: 533.2700 (Calcd for $C_{31}H_{42}O_4SNa$: 533.2699). MS *m/z*: 533 (M^++Na), 135.

(*S*)-**3b**: ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.58 (3H, s), 0.92—2.32 (19H, m, overlap with signals of the other diastereomer), 0.99 (3H, s), 1.62 (3H, d,

J=7.1 Hz), 2.03 (3H, s), 2.52 (1H, t, J=8.6 Hz, overlap with signals of the other diastereomer), 3.79 (3H, s, overlap with signals of the other diastereomer), 4.60 (1H, m, overlap with signals of the other diastereomer), 4.72 (1H, q, J=7.1 Hz), 5.36 (1H, m, overlap with signals of the other diastereomer), 6.84 (1H, dd, J=8.6, 1.5 Hz, overlap with signals of the other diastereomer), 7.26 (2H, d, J=8.6 Hz, overlap with signals of the other diastereomer).

(*R*)-**4b**: ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.69 (3H, s), 0.92—2.32 (19H, m, overlap with signals of the other diastereomer), 1.02 (3H, s), 1.63 (3H, d, J=7.1 Hz), 2.03 (3H, s), 2.52 (1H, t, J=8.6 Hz, overlap with signals of the other diastereomer), 3.79 (3H, s, overlap with signals of the other diastereomer), 4.60 (1H, m, overlap with signals of the other diastereomer), 4.73 (1H, q, J=7.1 Hz), 5.36 (1H, m, overlap with signals of the other diastereomer), 6.84 (1H, dd, J=8.6, 1.5 Hz, overlap with signals of the other diastereomer), 7.26 (2H, d, J=8.6 Hz, overlap with signals of the other diastereomer).

3β-Acetoxy-10,13-dimethyl-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1*H*-cyclopenta[*a*]phenanthrene-17-carboxylic Acid 1-(4-Chlorophenyl)ethyl Thioester (**3c**, **4c**): White solid. mp 120—123 °C. IR (KBr) cm^{-1}: 1730, 1682. FAB-MS *m/z*: 515.2394 (Calcd for $C_{30}H_{40}O_3ClS$: 515.2401). MS *m/z*: 517 (MH^++2), 515 (M^++H), 139.

(*S*)-**3c**: ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.54 (3H, s), 0.96—2.33 (19H, m, overlap with signals of the other diastereomer), 0.99 (3H, s), 1.61 (3H, d, J=7.2 Hz), 2.03 (3H, s), 2.52 (1H, t, J=9.0 Hz, overlap with signals of the other diastereomer), 4.60 (1H, m, overlap with signals of the other diastereomer), 4.72 (1H, q, J=7.2 Hz), 5.36 (1H, m, overlap with signals of the other diastereomer), 7.26—7.30 (4H, m, overlap with signals of the other diastereomer).

(*R*)-**4c**: ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.68 (s, 3H), 0.96—2.33 (19H, m, overlap with signals of the other diastereomer), 1.02 (3H, s), 1.62 (3H, d, J=7.2 Hz), 2.04 (3H, s), 2.52 (1H, t, J=9.0 Hz, overlap with signals of the other diastereomer), 4.60 (1H, m, overlap with signals of the other diastereomer), 4.72 (1H, q, J=7.2 Hz), 5.36 (1H, m, overlap with signals of the other diastereomer), 7.26—7.30 (5H, m, overlap with signals of the other diastereomer).

3β-Acetoxy-10,13-dimethyl-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1*H*-cyclopenta[*a*]phenanthrene-17-carboxylic Acid 1-Naphthalen-2-yl-ethyl Thioester (**3d**, **4d**): White solid. mp 136—138 °C. IR (KBr) cm^{-1}: 1730, 1682. FAB-MS *m/z*: 531.2928 (Calcd for $C_{34}H_{43}O_3S$: 531.2924). MS *m/z*: 531 (M^++H), 155.

(*S*)-**3d**: ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.57 (3H, s), 0.94—2.33 (19H, m, overlap with signals of the other diastereomer), 0.97 (3H, s), 1.74 (3H, d, J=7.2 Hz), 2.02 (3H, s), 2.54 (1H, t, J=8.9 Hz, overlap with signals of the other diastereomer), 4.59 (1H, m, overlap with signals of the other diastereomer), 4.94 (1H, q, J=7.2 Hz), 5.36 (1H, m, overlap with signals of the other diastereomer), 7.42—7.49 (3H, m, overlap with signals of the other diastereomer), 7.79—7.83 (4H, m, overlap with signals of the other diastereomer).

(*R*)-**4d**: ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.71 (3H, s), 0.94—2.33 (19H, m, overlap with signals of the other diastereomer), 1.03 (3H, s), 1.75 (3H, d, J=7.1 Hz), 2.04 (3H, s), 2.54 (1H, t, J=8.9 Hz, overlap with signals of the other diastereomer), 4.59 (1H, m, overlap with signals of the other diastereomer), 4.94 (1H, q, J=7.1 Hz), 5.36 (1H, m, overlap with signals of the other diastereomer), 7.42—7.49 (3H, m, overlap with signals of the other diastereomer), 7.79—7.83 (4H, m, overlap with signals of the other diastereomer).

3β-Acetoxy-10,13-dimethyl-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1*H*-cyclopenta[*a*]phenanthrene-17-carboxylic Acid 1-(2-Pyridinyl)-ethyl Thioester (**3e**, **4e**): White solid. mp 108—110 °C. IR (KBr) cm^{-1}: 1730, 1682. FAB-MS *m/z*: 482.2710 (Calcd for $C_{29}H_{40}O_3NS$: 482.2691). MS *m/z*: 482 (M^++H), 154.

(*S*)-**3e**: ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.56 (3H, s), 0.97—2.33 (19H, m, overlap with signals of the other diastereomer), 0.98 (3H, s), 1.69 (3H, d, J=7.0 Hz, overlap with signals of the other diastereomer), 2.03 (3H, s), 2.55 (1H, t, J=9.0 Hz), 4.60 (1H, m, overlap with signals of the other diastereomer), 4.86 (1H, q, J=7.1 Hz), 5.36 (1H, m, overlap with signals of the other diastereomer), 7.15 (1H, m, overlap with signals of the other diastereomer), 7.32 (1H, dd, J=7.7, 0.9 Hz, overlap with signals of the other diastereomer), 7.62 (1H, td, J=7.7, 2.4 Hz), 8.57 (1H, m, overlap with signals of the other diastereomer).

(*R*)-**4e**: ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.68 (3H, s), 0.97—2.33 (19H, m, overlap with signals of the other diastereomer), 1.02 (3H, s), 1.69 (3H, d, J=7.1 Hz, overlap with signals of the other diastereomer), 2.04 (3H, s), 2.56 (1H, t, J=8.9 Hz), 4.60 (1H, m, overlap with signals of the other diastereomer), 4.86 (1H, q, J=7.1 Hz), 5.36 (1H, m, overlap with signals of the other diastereomer), 7.15 (1H, m, overlap with signals of the other diastereomer), 7.32 (1H, dd, J=7.7, 0.9 Hz, overlap with signals of the other diastereomer), 7.63 (1H, td, J=7.7, 2.4 Hz), 8.57 (1H, m, overlap with signals of the other diastereomer).

3β-Acetoxy-10,13-dimethyl-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1*H*-cyclo-penta[*a*]phenanthrene-17-carboxylic Acid 1-Phenylpropyl-2-thioester (**3f**, **4f**): White solid. mp 113—115 °C. IR (KBr) cm^{-1}: 1730, 1680. FAB-MS *m/z*: 495.2918 (Calcd for $C_{31}H_{43}O_3S$: 495.2903). MS *m/z*: 495 (M^++H), 154.

(*S*)-**3f**: ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.55 (3H, s), 0.94—2.33 (19H, m, overlap with signals of the other diastereomer), 1.06 (3H, s), 1.24 (3H, d, J=7.0 Hz), 2.03 (3H, s, overlap with signals of the other diastereomer), 2.52 (1H, m, overlap with signals of the other diastereomer), 2.71 (1H, d, A part of AB, J_{AB}=13.6 Hz, J=6.9 Hz), 2.93 (1H, d, B part of AB, J_{AB}=13.6 Hz, J=6.3 Hz), 3.81 (1H, m, overlap with signals of the other diastereomer), 4.60 (1H, m, overlap with signals of the other diastereomer), 5.37 (1H, m, overlap with signals of the other diastereomer), 7.20—7.33 (5H, m, overlap with signals of the other diastereomer).

(*R*)-**4f**: ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.66 (3H, s), 0.94—2.33 (19H, m, overlap with signals of the other diastereomer), 1.06 (3H, s), 1.26 (3H, d, J=7.2 Hz), 2.03 (3H, s, overlap with signals of the other diastereomer), 2.52 (1H, m, overlap with signals of the other diastereomer), 2.74 (1H, d, A part of AB, J_{AB}=13.3 Hz, J=6.4 Hz), 2.97 (1H, d, B part of AB, J_{AB}=13.3 Hz, J=6.1 Hz), 3.81 (1H, m, overlap with signals of the other diastereomer), 4.60 (1H, m, overlap with signals of the other diastereomer), 5.37 (1H, m, overlap with signals of the other diastereomer), 7.20—7.33 (5H, m, overlap with signals of the other diastereomer).

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