A New Synthesis of Arylacetic Esters Starting from Aromatic Aldehyde by the Use of Methyl (Methylthio)methyl Sulfoxide[1)]

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(Received January 12, 1979)

Methyl (methylthio)methyl sulfoxide was found to react with benzaldehyde in the presence of benzyltrimethylammonium hydroxide (Triton B), sodium hydroxide, or potassium hydroxide, affording 1-(methylsulfinyl)-1-(methylthio)-2-phenylethylene. Treatment of this product with hydrogen chloride in an alcohol gave the corresponding alkyl phenylacetate in high yield. The whole reaction sequence provides a new method for synthesizing phenylacetic esters starting from benzaldehyde. In a similar manner, (alkoxy-, halogen-, or alkyl-substituted phenyl)acetic esters could be synthesized from the corresponding aromatic aldehydes. The present method was shown to be also applicable to the production of (2-thienyl)acetic esters.

Methyl (methylthio)methyl sulfoxide (**1**) was first synthesized by substitution of chloromethyl methyl sulfoxide with methanethiolate anion[2)] and it was later disclosed that **1** could be more conveniently produced by oxidation of bis(methylthio)methane with hydrogen peroxide.[3)] To date, many papers on organic syntheses using **1** have been published and **1** has appeared to be a versatile reagent for making a variety of organic compounds, such as aldehydes,[4)] cyclic or acyclic ketones,[5)] α-hydroxy aldehydes,[6)] α-amino acids,[7)] and α-keto acids.[8)]

$$CH_2O + 2CH_3SH \xrightarrow{H^+} CH_2(SCH_3)_2 \xrightarrow{H_2O_2} CH_2(SCH_3)(SOCH_3)$$

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Most of these synthetic methods involve the treatment of **1** with a strong base such as sodium hydride, potassium hydride, or butyllithium to form the carbanion which, then, is subjected to the reaction with various types of functional groups, followed by the acid-catalyzed hydrolysis, to give the product having a new functional group. For example, an aldehyde (**4**) or its acetal derivative (**5**) can be respectively synthesized by sequential treatment of **1** with sodium hydride in the coexistence of an alkyl halide (**2**) in tetrahydrofuran (THF) to form an alkylated product (**3**) followed by the acid-catalyzed decomposition of **3** either in the absence or in the presence of an orthoformate.[4)]

$$\underset{\mathbf{2}}{1} + RX \xrightarrow[THF]{NaH} \underset{\mathbf{3}}{RCH(SCH_3)(SOCH_3)} \xrightarrow{H^+} \underset{\mathbf{4}}{RCHO}\ \underset{\mathbf{5}}{[RCH(OR')_2]}$$

During the course of our investigation to search further synthetic utility of this new reagent (**1**), we observed that **1** underwent the Knoevenagel-type condensation with an aromatic aldehyde (**6**) in the presence of a base such as benzyltrimethylammonium hydroxide (Triton B), sodium hydroxide, or potassium hydroxide to give a 2-aryl-1-(methylsulfinyl)-1-(methylthio)ethylene (**7**) in high yield. Furthermore, the condensate (**7**) was found to be converted to an arylacetic ester (**8**) on treatment with hydrogen chloride in an alcohol. This whole reaction sequence provided a new synthetic route for conversion of aromatic aldehydes into the corresponding arylacetic esters. In this paper, we wish to report a full experimental detail on synthesis of arylacetic esters starting from aromatic aldehydes by the use of **1**.

$$\underset{\mathbf{6}}{ArCHO} + \mathbf{1} \xrightarrow{base} \underset{\mathbf{7}}{ArCH{=}C(SCH_3)(SOCH_3)} \xrightarrow[ROH]{HCl} \underset{\mathbf{8}}{ArCH_2COOR}$$

Results and Discussion

Transformation of Benzaldehyde into Phenylacetic Esters. When a mixture of benzaldehyde and methyl (methylthio)methyl sulfoxide (**1**) was treated with Triton B in refluxing THF, 1-(methylsulfinyl)-1-(methylthio)-2-phenylethylene (**10**) was formed: To a solution containing 2.57 g of **1** and 3 ml of benzaldehyde (**9**) in 5 ml of THF, was added 2 ml of 40% methanolic solution of Triton B, and then the resulting mixture was refluxed for 4 h. Separation by column-chromatography on silica gel gave 3.99 g (91% yield) of **10** as a colorless oil, bp 149—150 °C/0.08 Torr. When one mol-equiv of **9** was used in this condensation reaction, the yield of **10** was 80%. The structure of **10** was assigned on the basis of the following evidence.

$$\underset{\mathbf{9}}{\mathbf{1} + PhCHO} \xrightarrow{base} \underset{\mathbf{10}}{Ph(H)C{=}C(SCH_3)(SOCH_3)} \underset{}{\overset{h\nu}{\rightleftharpoons}} \underset{\mathbf{11}}{Ph(H)C{=}C(SOCH_3)(SCH_3)}$$

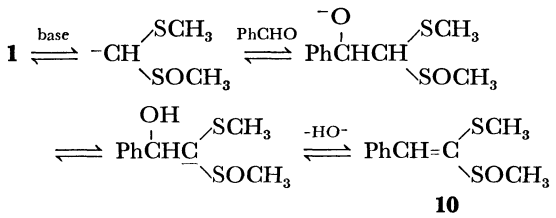
Molecular formula, $C_{10}H_{12}OS_2$, for this oil was confirmed by its mass spectrum (parent peak, *m/e* 212) and elemental analysis. The NMR and IR spectra proved that it consisted of only one stereoisomer and that it had a phenyl group [NMR in CCl_4: δ=7.32 (3H, m) and 7.85 (2H, m); IR: 756 and 692 cm^{-1}], an olefinic proton [δ=7.51 (1H, s)], a methylsulfinyl group [δ=2.62 (3H, s); 1062 cm^{-1}], and a methylthio group [δ=2.26 (3H, s)]. Reduction of this oil with lithium aluminium hydride afforded 1,1-bis(methylthio)-2-phenylethane.[9)]

Another stereoisomer (**11**) was obtained by irradiation of **10** in methanol with a low-pressure mercury arc lamp (Vycor filter) as a mixture with **10**. The stereochemical structures of **10** and **11** were assigned by the comparison of the pseudo-contact effects of the shift reagent, tris(dipivaloylmethanato)europium [Eu(dpm)$_3$], which formed complexes at the oxygen atom of a sulfoxide,[10)] on the NMR chemical shifts of their olefinic protons. The singlet at δ=7.51 of **10** was shifted downfield to δ=16.49 by adding 0.51

equiv of $Eu(dpm)_3$, while the olefinic proton ($\delta=7.02$ in CCl_4) of **11** appeared at $\delta=9.71$ in CCl_4–$Eu(dpm)_3$ (0.51 equiv). These facts indicate that the olefinic proton and the sulfinyl group of **10** are much closer in space than those of **11**. Hence, the stereochemical structure of **10** is established to be of *E*-configuration.

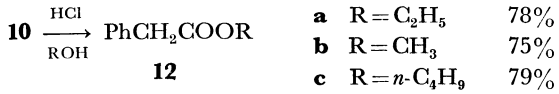
The condensation reaction of benzaldehyde with **1** could be also achieved under various basic conditions. Reflux of a solution containing **1**, benzaldehyde, and potassium hydroxide (1.3 equiv) in methanol gave **10** in 44% yield. When benzaldehyde was treated with sodium hydroxide (0.6 equiv) in two mol-equiv of **1** at 70 °C, **10** was obtained in 84% yield. Furthermore, it was found that stirring a mixture of benzaldehyde, **1**, and sodium hydride either in THF at 60 °C or in *N*,*N*-dimethylformamide at room temperature gave **10** in 56% or 43% yield, respectively.

This condensation reaction is very interesting because the reaction proceeds smoothly without removal of the formed water, and even in methanol. This may be accounted for by the incapability of **10** toward the Michael-type addition of hydroxide anion, that is, the irreversible nature of the final stage of the process, *i.e.* the elimination of hydroxide anion, as shown in Scheme 1.



Scheme 1.

The degradation of **10** with hydrogen chloride took place easily in an alcohol. A solution containing 300 mg of **10** in 10 ml of ethanol was bubbled with hydrogen chloride gas under ice-cooling and then was allowed to stand at room temperature. After evaporation *in vacuo*, the residue was column-chromatographed on silica gel to give 179 mg (78% yield) of ethyl phenylacetate (**12a**).[11] In a similar manner, methyl phenylacetate (**12b**) and butyl phenylacetate (**12c**) were obtained in 75% and 79% yields by the reaction with hydrogen chloride in methanol and 1-butanol, respectively.

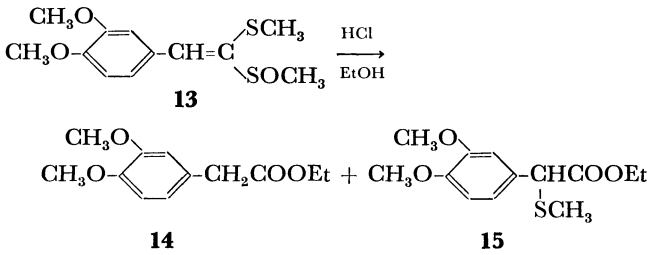


It should be noted that saturation of hydrogen chloride was not always necessary to the conversion of **10** into **12**. The concentration of hydrogen chloride in the system could be reduced to 0.1 M although a higher temperature was required in order to complete the reaction within a short time: Ethyl phenylacetate (**12a**) was produced in 75% yield by refluxing a solution of **10** in ethanol containing hydrogen chloride at the concentration of 0.1 M. When a solution of **10** in 1,2-dimethoxyethane was treated with conc. hydrochloric acid at room temperature, phenylacetic acid was isolated in 63% yield.

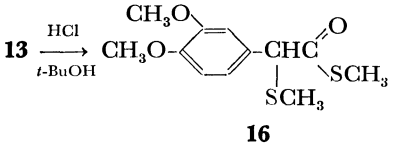
Thus, methyl (methylthio)methyl sulfoxide (**1**) was shown to be a novel reagent for the transformation of benzaldehyde into phenylacetic acid and its alkyl esters. The generality of this transformation was further investigated by examination of the reactions starting from a wide variety of aromatic aldehydes, and the results are described in the following.

Synthesis of (Alkoxy-substituted phenyl)acetic Esters. Many of (alkoxy-substituted phenyl)acetic acids are known as key-intermediates for the syntheses of isoquinoline alkaloids,[12] and it seemed very important to examine the production of these acids or their esters by using the above-mentioned procedure. The alkoxy-substituted benzaldehydes which we investigated were *p*-methoxybenzaldehyde, *p*-butoxybenzaldehyde, *p*-(benzyloxy)benzaldehyde, 3,4-dimethoxybenzaldehyde, 3,4-(methylenedioxy)benzaldehyde, and 3,4,5-trimethoxybenzaldehyde. The results are summarized in Tables 1 and 2, showing that all the aldehydes examined can be transformed in good yields into the corresponding arylacetic esters *via* the condensates with **1**.

When the condensate **13** derived from 3,4-dimethoxybenzaldehyde was treated with a saturated ethanolic solution of hydrogen chloride, ethyl (3,4-dimethoxyphenyl)(methylthio)acetate (**15**) was produced as a by-product (27% yield), resulting in formation of the expected ethyl (3,4-dimethoxyphenyl)acetate (**14**) in relatively low yield (40%). This could be overcome by reducing the concentration of hydrogen chloride: **14** was obtained in 91% yield on treatment of **13** with 0.5 M hydrogen chloride in ethanol.

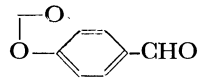
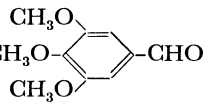
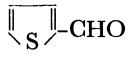


On the other hand, when a solution of **13** in *t*-butyl alcohol was saturated with hydrogen chloride, methanethiol ester (**16**) of (3,4-dimethoxyphenyl)(methylthio)acetic acid was isolated in 67% yield instead of *t*-butyl (3,4-dimethoxyphenyl)acetate.



Miscellaneous. By the present procedure, (halogen- or alkyl-substituted phenyl)acetic esters could be synthesized. On treatment with saturated alcoholic solution of hydrogen chloride, 2-(*p*-chlorophenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene which was derived from *p*-chlorobenzaldehyde and **1** was transformed into ethyl, methyl, or butyl ester of (*p*-chlorophenyl)acetic acid in 92%, 78%, or 80% yield, respectively. In analogous manners, ethyl (*o*-bromophenyl)acetate and ethyl (*p*-isopropylphenyl)acetate were also obtained, starting from *o*-bromobenzaldehyde and

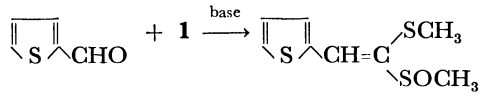
Table 1. Condensation of aromatic aldehydes with **1**

Aldehyde	Base[a]	Solvent	Temp	Yield (%)
CH_3O-C$_6$H$_4$-CHO	Triton B	THF	reflux	82 (100)[d]
	NaOH	—[b]	70 °C	93
n-BuO-C$_6$H$_4$-CHO	Triton B	THF	reflux	74
$PhCH_2O$-C$_6$H$_4$-CHO	Triton B	THF	reflux	62
	NaOH	—[c]	70—80 °C	92
PhO-C$_6$H$_4$-CHO	Triton B	THF	reflux	61
	NaOH	—[b]	70 °C	73
CH_3O, CH_3O-C$_6$H$_3$-CHO	Triton B	Dioxane	80 °C	47 (87)[d]
	Triton B	THF	reflux	66
	NaOH	—[b]	70 °C	82
	Triton B	THF	reflux	62 (81)[d]
	NaOH	—[b]	70 °C	84
	Triton B	THF	reflux	71
Cl-C$_6$H$_4$-CHO	Triton B	Dioxane	80 °C	51 (73)[d]
	Triton B	THF	reflux	65
	NaOH	—[b]	70 °C	70
Br, CHO-C$_6$H$_3$	Triton B	THF	reflux	51
i-Pr-C$_6$H$_4$-CHO	Triton B	THF	reflux	68
	NaOH	—[c]	60 °C	83
	Triton B	THF	reflux	86
	KOH	Methanol	reflux	83

a) Triton B=benzyltrimethylammonium hydroxide. b) The amount of **1** was 2.0 mol-equiv to the aldehyde. c) The aldehyde: **1**=1 : 2.56. d) Based on the unrecovered **1**. e) The aldehyde: **1**=1 : 1.5.

p-isopropylbenzaldehyde, as shown in Tables 1 and 2.

The present method was also applied to synthesis of (2-thienyl)acetic acid which was especially useful as a reagent for chemical modification of antibiotic penicillins and cephalosporins.[13] It was found that 2-thiophenecarbaldehyde underwent the condensation reaction with **1** in the presence of Triton B (86% yield) or potassium hydroxide (83% yield) in THF or methanol, respectively, under refluxing with heating, and then, on treatment of the resulting 1-(methylsulfinyl)-1-(methylthio)-2-(2-thienyl)ethylene (**17**) with 1 M hydrogen chloride in ethanol, ethyl (2-thienyl)acetate (**18**) was produced in 80% yield.[14] This method is suitable for making (2-thienyl)acetic esters, since 2-thiophenecarbaldehyde is easily available by the Vilsmeier-Haak reaction of thiophene.[15]



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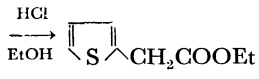

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Experimental

*Condensation of Benzaldehyde with **1**. (a) Triton B in THF*: To a solution containing 2.572 g of **1** and 3 ml of benzaldehyde in 5 ml of THF, was added a 40% methanolic solution (3 ml) of Triton B and the resulting mixture was refluxed for 4 h. After adding 100 ml of dichloromethane, the mixture was washed with 0.5 M sulfuric acid, dried (Na_2SO_4), and evaporated *in vacuo*. The residue was separated by column-chromatography on silica gel (using dichloromethane as an eluent) to afford 3.994 g of **10** as a colorless oil which was further purified by distillation *in vacuo*: bp 149—150 °C/0.08 Torr; IR (neat) 1062 cm^{-1}; NMR (CCl_4) δ=2.26 (3H, s), 2.62 (3H, s), 7.32 (3H, m), 7.51 (1H, s), and 7.85 (2H, m); MS (70 eV), *m/e* (relative intensity), 212 (M^+, 7), 197 (5), 149 (100), 134 (96), 116 (18), 115 (14), and 89 (11). Found: C, 56.56; H, 5.70; S, 30.20%. Calcd for $C_{10}H_{12}OS_2$: C, 56.65; H, 5.72; S, 30.33%.

The above-mentioned reaction was repeated using an equimolar amount of benzaldehyde to **1**. To a solution containing benzaldehyde (1.007 g) and **1** (1.17 g) in THF (10 ml), was added a 40% methanolic solution (1.2 ml) of Triton B and the resulting mixture was refluxed for 4 h. After the addition of dichloromethane (50 ml), the solution was washed with 0.5 M sulfuric acid (20 ml) and water (50 ml × 2), dried (Na_2SO_4), and evaporated *in vacuo*. The residue was column-chromatographed on silica gel (benzene–dichloro-

Table 2. Yield of alkyl arylacetate (**8**) in the reaction of 2-aryl-1-(methylsulfinyl)-1-(methylthio)ethylene (**7**) with hydrogen chloride in an alcohol

Ar	Alcohol	Concentration of HCl	Temp	Yield (%)
CH_3O-C$_6$H$_4$-	EtOH	saturation	room temp	94
n-BuO-C$_6$H$_4$-	EtOH	1 M	reflux	81
$PhCH_2O$-C$_6$H$_4$-	EtOH	1 M	reflux	82
PhO-C$_6$H$_4$-	EtOH	1 M	reflux	85
	EtOH	saturation	room temp	40[a]
CH_3O, CH_3O-C$_6$H$_3$-	EtOH	0.5 M	—[b]	91
	t-BuOH	saturation	room temp	—
O—CH$_2$—O-C$_6$H$_3$-	EtOH	saturation	room temp	91
	MeOH	saturation	room temp	80
CH_3O, CH_3O, CH_3O-C$_6$H$_2$-	EtOH	saturation	room temp	62
	EtOH	1 M	reflux	72
Cl-C$_6$H$_4$-	EtOH	saturation	room temp	92
	MeOH	saturation	room temp	78
	n-BuOH	saturation	room temp	80
Br-C$_6$H$_4$-	EtOH	1 M	reflux	92
i-Pr-C$_6$H$_4$-	EtOH	1 M	reflux	96
2-thienyl	EtOH	1 M	room temp	80
	EtOH	0.7 M	reflux	76

a) Methanethiol ester of (3,4-dimethoxyphenyl)(methylthio)acetic acid was isolated in 67% yield. b) Room temp → reflux.

methane (1 : 3)] to give **10** (1.606 g: 80% yield) as a pale yellow oil.

(b) KOH in Methanol: A solution containing benzaldehyde (505 mg) and **1** (585 mg) in methanol (5 ml) was refluxed for 4 days after potassium hydroxide (350 mg) was added. Dichloromethane (30 ml) was added and the resulting mixture was washed with 0.5 M sulfuric acid (10 ml) and water (30 ml×2). After being dried (Na_2SO_4) and evaporated *in vacuo*, the residue was column-chromatographed on silica gel [benzene–dichloromethane (1 : 2)] to give **10** (442 mg: 44% yield) as a pale yellow oil.

(c) NaOH and Excess of 1: After a mixture of **1** (2.34 g) and powdered sodium hydroxide (0.32 g) was stirred at 70 °C for 30 min, benzaldehyde (0.98 g) was added and then the resulting mixture was further stirred at 70 °C for 1 h. After the addition of dichloromethane (50 ml), the mixture was washed with 0.5M sulfuric acid (20 ml) and water (50 ml×2) and, the organic layer was dried (Na_2SO_4). Evaporation *in vacuo* gave a yellow oil which was column-chromatographed on silica gel [benzene–dichloromethane (1 : 3)] to afford **10** (1.654 g: 84% yield) as a pale yellow oil.

(d) NaH in DMF: To a solution containing **1** (6.00 g) in DMF (20 ml), was added sodium hydride (65% oil-dispersion; 1.80 g) and the resulting mixture was stirred at room temperature for 1.5 h. After the dropwise addition of benzaldehyde (4.80 g) over 10 min under ice-cooling, the mixture was further stirred at room temperature for 2 h, and then dichloromethane (100 ml) was added. After being washed with water (70 ml×2), the organic layer was dried ($MgSO_4$) and evaporated *in vacuo* to give an oily residue which was separated by column-chromatography on silica gel [benzene–dichloromethane (1 : 3)] to afford **10** (4.11 g: 43% yield) as a pale yellow oil.

(e) NaH in THF: To a solution of **1** (6.00 g) in THF (20 ml), was added sodium hydride (65% oil-dispersion; 1.80 g) and the resulting mixture was stirred at room temperature for 1 h. After the dropwise addition of benzaldehyde (4.90 g) over 10 min at room temperature, the reaction mixture was further stirred at 60 °C for 1.5 h and then dichloromethane (100 ml) was added. After insoluble matters were filtered off, the filtrate was washed with water (70 ml×2), dried ($MgSO_4$), and evaporated *in vacuo*. The residue was column-chromatographed on silica gel [benzene–dichloromethane (1 : 3)] to afford **10** (5.50 g: 56% yield) as a pale yellow oil.

Photochemical Isomerization of 10: A solution of the 1-(methylsulfinyl)-1-(methylthio)-2-phenylethylene (**10**, 276 mg), which was obtained by the above-mentioned reaction, in methanol (200 ml) was irradiated with a low-pressure mercury arc lamp (10 W) through Vycor filter for 2 h and 45 min. After evaporation *in vacuo*, the residue was column-chromatographed on silica gel (dichloromethane) to give a pale yellow oil (211 mg) which was shown by an NMR analysis to consist of **10** and its geometric isomer (**11**) in the ratio of 58 : 42. Found: C, 56.66; H, 5.71; S, 30.02%.

Calcd for $C_{10}H_{12}OS_2$: C, 56.56; H, 5.70; S, 30.20%.

The NMR signals of **11** appeared at δ=2.60 (3H, s), 2.47 (3H, s), 7.02 (1H, s) and 7.26 (5H, s) in CCl_4.

*Decomposition of **10** with Hydrogen Chloride (HCl). (a) In Saturated Methanolic Solution of HCl*: HCl gas was bubbled in a solution of **10** (514 mg) in methanol (5 ml) under cooling with ice–water until HCl was saturated. The resulting solution was stirred at room temperature for 19 h and then was evaporated *in vacuo*. The residue was column-chromatographed on silica gel [hexane–benzene (1 : 1)] to give methyl phenylacetate (271 mg: 75% yield) as a colorless oil which was identified by the comparison of its IR and NMR spectra with those of the authentic sample prepared from phenylacetic acid by the usual method (HCl–methanol).

(b) In Saturated Ethanolic Solution of HCl: A solution containing **10** (300 mg) in ethanol (10 ml) was saturated with HCl gas. The introduction of the gas was performed under ice-cooling. The resulting solution was stirred at room temperature for 8 h and concentrated *in vacuo*. The residue was separated by column-chromatography on silica gel (benzene) to give ethyl phenylacetate (179 mg: 77% yield) which was identified by the comparison of its IR and NMR spectra with those of the authentic sample obtained by saturation of HCl in ethanolic solution of phenylacetic acid.

(c) In 0.1M Ethanolic Solution of HCl: To a solution of **10** (505 mg) in ethanol (10 ml), was added a saturated ethanolic solution (0.1 ml) of HCl and the resulting solution was refluxed for 25 h. After evaporation *in vacuo*, the residue was subjected to column-chromatography on silica gel [hexane–benzene (1 : 1)] to afford ethyl phenylacetate (291 mg: 75% yield) as a pale yellow oil. Since a further elution with ethyl acetate afforded the starting material (**10**, 77 mg), the conversion yield of ethyl phenylacetate was calculated to be 88%.

(d) In 1-Butanol: A solution of **10** (1.763 g) in 1-butanol (10 ml) was saturated with HCl gas under cooling with ice–water and then the resulting solution was stirred at room temperature for 3 h. After evaporation *in vacuo*, the residue was column-chromatographed on silica gel [hexane–benzene (4 : 1)] to give butyl phenylacetate (1.418 g: 89% yield) as a colorless oil, which was identified by the comparison of its IR and NMR spectra with those of the authentic sample.[16]

(e) Concd Hydrochloric Acid: To a solution containing **10** (191 mg) in 1,2-dimethoxyethane (1.5 ml), was added concd hydrochloric acid (1 ml) and the resulting mixture was stirred at room temperature for 3 h. Then, dichloromethane (50 ml) and water (5 ml) were added. The aqueous layer was separated and further extracted with dichloromethane (50 ml). The organic layers were combined, dried (Na_2SO_4), and evaporated *in vacuo*. After the addition of ether (30 ml) to the residue, the solution was extracted with a saturated aqueous solution (10 ml×2) of sodium hydrogen carbonate. The aqueous layer was acidified with hydrochloric acid and extracted with dichloromethane (30 ml×3). The organic layer was dried (Na_2SO_4) and evaporated *in vacuo* to afford phenylacetic acid (77 mg: 63% yield) as colorless crystals having mp 69—75 °C. The identification was achieved by the comparison of its IR and NMR spectra with those of an authentic sample and the mixture mp.

Condensation of p-*Methoxybenzaldehyde with **1**. (a) Triton B in THF*: To a solution of **1** (951 mg) and *p*-methoxybenzaldehyde (1.17 g) in THF (10 ml), was added a 40% methanolic solution (1 ml) of Triton B and the mixture was refluxed for 5 h. Then, dichloromethane (100 ml), water (5 ml), and 4.5 M sulfuric acid (2 ml) were added and the mixture was shaken. The organic layer was separated, dried (Na_2SO_4), and evaporated *in vacuo*. The residue was subjected to column-chromatography on silica gel (dichloromethane) to obtain 2-(*p*-methoxyphenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**19**; 1.51 g: 82% yield) as a pale yellow oil: bp 170—173 °C/0.20 Torr; IR (neat) 1059 cm^{-1}; NMR (CCl_4) δ=2.30 (3H, s), 2.63 (3H, s), 3.84 (3H, s), 6.86 (2H, d, J=8.4 Hz), 7.43 (1H, s), and 7.86 (2H, d, J=8.4 Hz); MS (70 eV), *m/e* (relative intensity), 242 (M^+, 6), 179 (87), 164 (100), 149 (41), 146 (39), and 121 (15). Found: C, 54.55; H, 5.84; S, 26.50%. Calcd for $C_{11}H_{14}O_2S_2$: C, 54.52; H, 5.82; S, 26.46%.

Further elution gave **1** (176 mg). Therefore, the conversion yield of **19** was calculated to be 100%.

*(b) NaOH and Excess of **1***: After a mixture of **1** (9.13 g) and powdered sodium hydroxide (0.45 g) was stirred at 70 °C for 30 min, *p*-methoxybenzaldehyde (4.87 g) was dropwise added and the resulting mixture was further stirred at 70 °C for 1.5 h. After the addition of dichloromethane (100 ml), the mixture was washed with 0.5 M sulfuric acid (30 ml) and water (100 ml×2) and then the organic layer was dried (Na_2SO_4). Evaporation *in vacuo*, followed by column-chromatography on silica gel [dichloromethane–ethyl acetate (4 : 1)], gave **19** (8.068 g: 93% yield) as a yellow oil.

*Decomposition of 2-(*p*-Methoxyphenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**19**) with HCl.* A solution containing **19** (274 mg) in ethanol (10 ml) was saturated with HCl gas under cooling with ice–water and allowed to stand overnight at room temperature. After evaporation *in vacuo*, the residue was column-chromatographed on silica gel [hexane–benzene (1 : 1)] to give ethyl (*p*-methoxyphenyl)acetate (206 mg: 94% yield). This ester was identified by the comparison of its IR and NMR spectra with those of the authentic sample which was obtained by the usual esterification (HCl–ethanol) of (*p*-methoxyphenyl)acetic acid given in the following.

To a solution containing **19** (460 mg) in 1,2-dimethyoxyethane (2 ml), was added concd hydrochloric acid (1 ml) and the resulting mixture was stirred for 15 h at room temperature. After the reaction mixture was shaken with diethyl ether (50 ml), the organic layer was separated, which was extracted with an aqueous solution of potassium carbonate. The aqueous layer was acidified with concd hydrochloric acid, and then extracted with dichloromethane (50 ml×3). The organic layer was dried (Na_2SO_4) and evaporated *in vacuo* to give 62 mg of colorless crystals, which were identified as (*p*-methoxyphenyl)acetic acid by the comparison of their IR and NMR spectra with those reported in the Sadtler spectra.

Condensation of p-*Butoxybenzaldehyde with **1***. To a solution of *p*-butoxybenzaldehyde (5.05 g) and **1** (4.26 g) in THF (50 ml), was added a 40% methanolic solution (4 ml) of Triton B and the resulting solution was refluxed for 24.5 h. Dichloromethane (50 ml) was added and the mixture was washed with 0.5 M sulfuric acid. After being dried (Na_2SO_4) and evaporation *in vacuo*, the residue was subjected to column-chromatography on silica gel [benzene–dichloromethane (1 : 1)] to give 2-(*p*-butoxyphenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**20**; 5.94 g: 74% yield) as a pale yellow oil which soon crystallized and was further purified by recrystallization from hexane to afford colorless crystals: mp 47—48 °C; IR (KBr) 1055 cm^{-1}; NMR($CDCl_3$) δ=0.94 (3H, t, J=6 Hz), 1.20—1.88 (4H, m), 2.22 (3H, s), 2.64 (3H, s), 3.90 (2H, t, J=6 Hz), 6.84 (2H, d, J=9 Hz), 7.49 (1H, s), and 7.83 (2H, d, J=9

Hz); MS (70 eV), *m/e* (relative intensity), 284 (M^+, 13), 222 (17), 221 (100), 220 (11), 206 (37), 165 (50), 151 (11), 150 (99.7), 149 (27), 132 (40), 131 (29), 121 (24), 89 (11), 77 (12), 41 (18), and 29 (38). Found: C, 58.83; H, 7.02; S, 22.57%. Calcd for $C_{14}H_{20}O_2S_2$: C, 59.12; H, 7.09; S, 22.54%.

*Decomposition of 2-(p-Butoxyphenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**20**) with HCl.* To a solution of **20** (492 mg) in ethanol (9 ml), was added a saturated ethanolic solution (1 ml) of HCl and the resulting solution was refluxed for 3 h. After evaporation *in vacuo*, the residue was column-chromatographed on silica gel (benzene) to give ethyl (*p*-butoxyphenyl)acetate (330 mg: 81% yield) as a pale yellow oil: IR (neat) 1783 cm^{-1}; NMR ($CDCl_3$) δ=0.93 (3H, t, J=7 Hz), 1.19 (3H, t, J=7 Hz), 1.20—1.86 (4H, m), 3.46 (2H, s), 3.86 (2H, t, J=6 Hz), 4.06 (2H, q, J=7 Hz), 6.76 (2H, d, J=9 Hz), and 7.11 (2H, d, J=9 Hz).

This ester was hydrolyzed without further purification. The ester (212 mg) was dissolved in 1,2-dimethoxyethane (5 ml) and 1 M aqueous solution (2.5 ml) of potassium hydroxide was added. The reaction mixture was stirred at room temperature for 45 h. After the addition of water (10 ml) and acidification with 0.5M sulfuric acid, the mixture was extracted with diethyl ether (30 ml×2). The organic layer was dried (Na_2SO_4) and evaporated *in vacuo* to give crude (*p*-butoxyphenyl)acetic acid as pale yellow crystals which were further purified by recrystallization from hexane to give colorless crystals: mp 87.5—88.5 °C; IR (KBr) 1701 cm^{-1}; NMR ($CDCl_3$) δ=0.94 (3H, t, J=7 Hz), 1.25—1.88 (4H, m), 3.50 (2H, s), 3.88 (2H, t, J=6 Hz), 6.78 (2H, d, J=8 Hz), 7.11 (2H, d, J=8 Hz), and 10.56 (1H, broad s). Found: C, 69.41; H, 7.72%. Calcd for $C_{12}H_{16}O_3$: C, 69.23; H, 7.68%.

*Condensation of p-(Benzyloxy)benzaldehyde with **1**. (a) Triton B in THF*: To a solution containing *p*-(benzyloxy)-benzaldehyde (999 mg) and **1** (590 mg) in THF (5 ml), was added a 40% methanolic solution of Triton B and the resulting solution was refluxed for 24 h. After the addition of dichloromethane (50 ml), the solution was washed successively with 0.5 M sulfuric acid (20 ml) and water (50 ml×2), dried (Na_2SO_4), and evaporated *in vacuo*. The residue was column-chromatographed on silica gel (dichloromethane) to give 2-(*p*-benzyloxyphenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**21**; 935 mg: 62% yield) as a yellow oil: IR (neat) 1063 cm^{-1}; NMR ($CDCl_3$) δ=2.24 (3H, s), 2.66 (3H, s), 5.03 (2H, s), 6.94 (2H, d, J=9 Hz), 7.2—7.5 (5H, m), 7.51 (1H, s), and 7.86 (2H, d, J=9 Hz). Found: C, 63.96; H, 5.73; S, 19.87%. Calcd for $C_{17}H_{18}O_2S_2$: C, 64.12; H, 5.70; S, 20.14%.

*(b) NaOH and Excess of **1***: A mixture of **1** (8.89 g) and sodium hydroxide (0.67 g) was stirred at 70 °C for 30 min, and then *p*-benzyloxybenzaldehyde (5.00 g) was added. The resulting mixture was further stirred at 70—80 °C for 1.5 h. After the addition of dichloromethane (100 ml), the mixture was washed with a saturated aqueous solution of sodium chloride and dried (Na_2SO_4). Evaporation *in vacuo*, followed by column-chromatography on silica gel [dichloromethane–ethyl acetate (19 : 1)], afforded **21** (6.909 g: 92% yield) as a pale yellow oil.

*Decomposition of 2-(p-Benzyloxyphenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**21**) with HCl.* To a solution of **21** (495 mg) in ethanol (9 ml), was added a saturated ethanolic solution (1 ml) of HCl and the resulting solution was refluxed for 3 h. After evaporation *in vacuo*, the residue was column-chromatographed on silica gel [benzene-hexane (4 : 1)] to afford ethyl (*p*-benzyloxyphenyl)acetate (343 mg: 82% yield) as a colorless oil: IR (neat) 1735 cm^{-1}; NMR ($CDCl_3$) δ=1.24 (3H, t, J=7 Hz), 3.56 (2H, s), 4.15 (2H, q, J=7 Hz), 5.07 (2H, s), 6.95 (2H, d, J=9 Hz), 7.24 (2H, d, J=9 Hz), and 7.3—7.5 (5H, m); MS (70 eV), *m/e* (relative intensity), 270 (M^+, 4), 92 (7), 91(100), and 65 (6).

This ester was hydrolyzed by the usual manner: The ester (198 mg) was dissolved in 1,2-dimethoxyethane (3 ml) and 1M aqueous solution (3 ml) of potassium hydroxide was added. The resulting mixture was stirred at room temperature for 19 h and then, water (10 ml) and 0.5 M sulfuric acid (5 ml) were added. After extraction with ethyl acetate (30 ml×3), the organic layer was dried (Na_2SO_4) and evaporated *in vacuo*. The residue was column-chromatographed on silica gel [dichloromethane–ethyl acetate (2 : 1)] to give (*p*-benzyloxyphenyl)acetic acid as colorless crystals: mp 124—125 °C (from chloroform-hexane)(lit,[17] mp 120—121 °C); IR (KBr) 3200—2300 and 1688 cm^{-1}; NMR ($CDCl_3$) δ=3.48 (2H, s), 4.95 (2H, s), 6.85 (2H, d, J=9 Hz) 7.15 (2H, d, J=9 Hz), 7.2—7.4 (5H, m), and 11.44 (1H, broad s). Found: C, 74.18; H, 5.78%. Calcd for $C_{15}H_{14}O_3$: C, 74.37; H, 5.82%.

*Condensation of m-Phenoxybenzaldehyde with **1**. (a) Triton B in THF*: To a solution of *m*-phenoxybenzaldehyde (2.00 g) and **1** (1.27 g) in THF (10 ml), was added a 40% methanolic solution (1 ml) of Triton B and the solution was refluxed for 26 h. Dichloromethane (50 ml) was added and the resulting solution was washed with 1.5 M sulfuric acid. The organic layer was dried (K_2CO_3) and evaporated *in vacuo*. The residue was subjected to column-chromatography on silica gel (dichloromethane) to give 1-(methylsufinyl)-1-(methylthio)-2-(*m*-phenoxyphenyl)ethylene (**22**; 1.88 g: 61% yield) as a pale yellow oil. An analytical sample was obtained by rechromatography as a colorless oil: IR (neat) 1062 cm^{-1}; NMR ($CDCl_3$) δ=2.20 (3H, s), 2.66 (3H, s), 6.88—7.60 (9H, m), and 7.52 (1H, s); MS (70 eV), *m/e* (relative intensity), 304 (M^+, 5), 242 (19), 241 (100), 227 (13), 226 (77), 197 (12), 165 (19), 148 (35), 147 (22), 89 (30), 77 (22), 63 (11), 51 (20), and 39 (10). Found: C, 63.20; H, 5.30; S, 21.06%. Calcd for $C_{16}H_{16}O_2S_2$: C, 63.13; H, 5.30; S, 20.83%.

*(b) NaOH and Excess of **1***: After a mixture of **1** (2.44 g) and powdered sodium hydroxide (120 mg) was stirred at 70 °C for 30 min, *m*-phenoxybenzaldehyde (1.99 g) was added and then the resulting mixture was further stirred at 70 °C for 3 h. After the addition of dichloromethane (50 ml), the mixture was washed successively with water (50 ml×2) and 0.5 M sulfuric acid (50 ml), dried ($MgSO_4$), and evaporated *in vacuo*. The residue was column-chromatographed on silica gel (dichloromethane) to give **22** (2.23 g: 73% yield) as a pale yellow oil.

*Decomposition of 1-(Methylsulfinyl)-1-(methylthio)-2-(m-phenoxyphenyl)ethylene (**22**) with HCl.* To a solution of **22** (492 mg) in ethanol (9 ml), was added a saturated ethanolic solution (1 ml) of HCl, and the solution was refluxed for 2.5 h. After evaporation *in vacuo*, the residue was subjected to column-chromatography on silica gel (benzene) to give ethyl (*m*-phenoxyphenyl)acetate (351 mg: 85% yield) as a colorless oil: IR (neat) 1736 cm^{-1}; NMR ($CDCl_3$) δ=1.14 (3H, t, J=7 Hz), 3.45 (2H, s), 4.02 (2H, q, J=7 Hz), and 6.60—7.40 (9H, m). Found: C, 74.50; H, 6.32%. Calcd for $C_{16}H_{16}O_3$: C, 74.98; H, 6.29%.

*Condensation of 3,4-Dimethoxybenzaldehyde with **1**. (a) Triton B in Dioxane*: To a solution containing 3,4-dimethoxybenzaldehyde (1.43 g) and **1** (1.078 g) in dioxane (7 ml), was added a 40% methanolic solution (1 ml) of Triton B and then the mixture was stirred for 25 h at 80 °C. After the addition of dichloromethane (100 ml), the resulting solution was washed with *ca.* 2 M hydrochloric acid (10.5

ml), dried (Na_2SO_4), and evaporated *in vacuo*. The residue was column-chromatographed on silica gel (dichloromethane) to afford 2-(3,4-dimethoxyphenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**13**) (1.118 g: 47% yield) as a colorless oil which crystallized on standing and was further purified by recrystallization from diethyl ether–hexane to give colorless crystals: mp 61.5—62.5 °C; IR (KBr) 1057 cm^{-1}: NMR ($CDCl_3$) δ=2.31 (3H, s), 2.72 (3H, s), 6.90 (1H, d, J=8.3 Hz), 7.46 (1H, dd, J=8.3 and 2.4 Hz), 7.55 (1H, s), and 7.73 (1H, d, J=2.4 Hz). Found: C, 52.83; H, 5.88%. Calcd for $C_{12}H_{16}O_3S_2$: C, 52.91; H, 5.92%.

Since **1** (493 mg) was recovered, the yield of **13** based on the consumed **1** was calculated to be 87%.

(b) Triton B in THF: To a solution containing 3,4-dimethoxybenzaldehyde (1.007 g) and **1** (0.75 g) in THF (5 ml), was added a 40% methanolic solution (0.75 ml) of Triton B and then the resulting solution was refluxed for 48 h. After the addition of dichloromethane (50 ml), the mixture was washed with 0.5 M sulfuric acid (20 ml) and water (50 ml×2), dried (Na_2SO_4), and evaporated *in vacuo*. The residue was subjected to column-chromatography on silica gel [dichloromethane and dichloromethane–ethyl acetate (4 : 1)] to give **13** (1.085 g: 66% yield) as a yellow oil which crystallized.

*(c) NaOH and Excess of **1***: After a mixture of **1** (7.48 g) and powdered sodium hydroxide (0.36 g) was stirred at 70 °C for 30 min, 3,4-dimethoxybenzaldehyde (5.007 g) was added and then the resulting mixture was further stirred at 70 °C for 1.5 h. After the addition of dichloromethane (100 ml), the mixture was washed with 0.5 M sulfuric acid (50 ml) and water (100 ml×2), dried (Na_2SO_4), and evaporated *in vacuo*. The residue was column-chromatographed on silica gel [dichloromethane–ethyl acetate (4 : 1)] to give **13** (6.714 g: 82% yield) as a yellow oil which crystallized after a while.

*Decomposition of **13** with HCl. (a) in Saturated Ethanolic Solution of HCl*: A solution of **13** (260 mg) in ethanol (10 ml) was saturated with HCl gas at room temperature. The temperature of the solution rose up to *ca.* 50 °C. The reaction mixture was allowed to stand overnight at room temperature and then evaporated *in vacuo*. The residue was subjected to column-chromatography on silica gel (benzene) to give ethyl (3,4-dimethoxyphenyl)acetate (**14**) (86 mg: 37% yield) and ethyl (3,4-dimethoxyphenyl)(methylthio)acetate (**15**) (135 mg: 49% yield). The identification of **14** was achieved by the comparison of its IR spectrum with that of the authentic sample prepared by the usual esterification (HCl–ethanol) of commercially available (3,4-dimethoxyphenyl)acetic acid. The structure of **15** was deduced by the following physical data: IR (neat) 1727 cm^{-1}; NMR (CCl_4) δ=1.26 (3H, t, J=7.5 Hz), 2.00 (3H, s), 3.79 (3H, s), 3.83 (3H, s), 4.15 (2H, q, J=7.5 Hz), 4.28 (1H, s), and 6.55—7.05 (3H, m).

In the above reaction, when HCl gas was passed into the system under ice-cooling until the solution turned yellow, the yields of **14** and **15** were 40% and 25%, respectively.

(b) In 0.5 M Ethanolic Solution of HCl: To a solution of **13** (2.00 g) in ethanol (20 ml), was added a saturated ethanolic solution (1 ml) of HCl and the solution was stirred at room temperature for 22 h and refluxed for 2 h. After evaporation *in vacuo*, the residue was subjected to column-chromatography on silica gel (benzene) to afford **14** (1.51 g: 91% yield) as a yellow oil.

(c) In t-Butyl Alcohol: After a solution of **13** (505 mg) in *t*-butyl alcohol (5 ml) was saturated with HCl under cooling with ice-water, the resulting solution was stirred at room temperature for 2 h. After evaporation *in vacuo*, the residue was column-chromatographed on silica gel [benzene–hexane (1:4)] to give a yellow oil (338 mg: 67% yield) which was assigned as **16** from the following properties: IR (neat) 1680 cm^{-1}; NMR (CCl_4) δ=2.05 (3H, s), 2.15 (3H, s), 3.78 (3H, s), 3.82 (3H, s), 4.49 (1H, s), 6.62—6.93 (3H, m). Found: C, 53.09; H, 5.69%. Calcd for $C_{12}H_{16}O_3S_2$: C, 52.91; H, 5.92%.

*Condensation of 3,4-(Methylenedioxy)benzaldehyde with **1**. (a) Triton B in THF*: To a solution containing **1** (674 mg) and 3,4-(methylenedioxy)benzaldehyde (895 mg) in THF (5 ml), was added a 40% methanolic solution (0.7 ml) of Triton B and then the resulting mixture was refluxed for 9 h. Dichloromethane (50 ml) was added and the mixture was washed with 0.5 M sulfuric acid, dried (Na_2SO_4), and evaporated *in vacuo*. The residue was column-chromatographed on silica gel (dichloromethane) to afford 2-(3,4-methylenedioxyphenyl)-1-(methylsulfinyl)-1-(methylthio)-ethylene (**23**; 870 mg: 62% yield) as a pale yellow oil: IR (neat) 1058 cm^{-1}; NMR ($CDCl_3$) δ=2.34 (3H, s), 2.76 (3H, s), 6.05 (2H, s), 6.87 (1H, d, J=8 Hz), 7.30 (1H, dd, J=8 and 2 Hz), 7.54 (1H, s), and 7.75 (1H, d, J=2 Hz). Found: C, 51.27; H, 4.65; S, 25.20%. Calcd for $C_{11}H_{12}O_3S_2$: C, 51.54; H, 4.72; S, 25.02%.

Further elution with dichloromethane gave **1** (151 mg). Therefore, the yield based on the unrecovered **1** was calculated to be 81%.

*(b) NaOH and Excess of **1***: After a mixture of **1** (2.44 g) and powdered sodium hydroxide (0.12 g) was stirred at 70 °C for 30 min, 3,4-(methylenedioxy)benzaldehyde (1.502 g) was added and then the resulting mixture was further stirred at 70 °C for 3 h. After the addition of dichloromethane (50 ml), the mixture was washed with water (50 ml×2), dried (Na_2SO_4), and evaporated *in vacuo*. The residue was column-chromatographed on silica gel (dichloromethane) to give **23** (2.143 g: 84% yield) as a pale yellow oil.

*Decomposition of 2-(3,4-Methylenedioxyphenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**23**) with HCl. (a) In Ethanol*: A solution of **23** (522 mg) in ethanol (10 ml) was bubbled by HCl gas under ice-cooling until the solution turned yellow (about 20 min). The reaction mixture was evaporated *in vacuo* and subjected to column-chromatography on silica gel (benzene) to afford ethyl (3,4-methylenedioxyphenyl)acetate (386 mg: 91% yield) as a pale yellow oil. Identification of the product was achieved by the comparison of its IR spectrum with that of the authentic sample prepared by the usual esterification (HCl–ethanol) of (3,4-methylenedioxyphenyl)-acetic acid which was obtained by the following procedure.

To a solution containing ethyl (3,4-methylenedioxyphenyl)-acetate (333 mg) in 1,2-dimethoxyethane (10 ml), was added 1 M aqueous solution (5 ml) of sodium hydroxide and the resulting mixture was refluxed for 2 h. After being poured into ice–water (50 ml) containing 3.5% hydrochloric acid (10 ml), the mixture was extracted with ethyl acetate (50 ml×2), dried (Na_2SO_4), and evaporated *in vacuo*. The residue was column-chromatographed on silica gel [dichloromethane–ethyl acetate (1:1)] to afford (3,4-methylenedioxyphenyl)-acetic acid (278 mg: 97% yield) as pale yellow crystals, which were further purified by recrystallization from diethyl ether–hexane to give colorless crystals: mp 132—133 °C (lit,[18] mp 128—129 °C); IR (KBr) 3300—2700 and 1703 cm^{-1}; NMR ($CDCl_3$) δ=3.50 (2H, s), 5.86 (2H, s), 6.66 (2H, diffused s), and 6.70 (1H, diffused s). Found: C, 60.10; H, 4.45%. Calcd for $C_9H_8O_4$: C, 60.00; H, 4.48%.

(b) In Methanol: A solution of **23** (309 mg) in methanol (4 ml) was saturated under ice-cooling with HCl and the resulting solution was stirred at room temperature for 15.5 h. After evaporation *in vacuo*, the residue was subjected to column-

chromatography on silica gel [benzene–hexane (1:4)] to afford methyl (3,4-methylenedioxyphenyl)acetate (183 mg: 80% yield) as a pale yellow oil which was identified by the comparison of its IR and NMR spectra with those of the authentic sample prepared by the usual esterification (HCl–methanol) of (3,4-methylenedioxyphenyl)acetic acid.

Condensation of 3,4,5-Trimethoxybenzaldehyde with **1**. To a solution of **1** (3.353 g) and 3,4,5-trimethoxybenzaldehyde (5.016 g) in THF (50 ml), was added a 40% methanolic solution (5 ml) of Triton B and the resulting solution was refluxed for 12 h. After the addition of dichloromethane (50 ml) followed by acidification with 4.5 M sulfuric acid, the organic layer was separated, washed with water, dried (Na_2SO_4), and evaporated *in vacuo*. The residue was separated by column-chromatography on silica gel (dichloromethane) to give 2-(3,4,5-trimethoxyphenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**24**; 5.465 g: 71% yield) as a yellow oil, which was crystallized from diethyl ether–hexane to afford colorless crystals: mp 86.5—87.5 °C; IR (KBr) 1058 cm^{-1}; NMR ($CDCl_3$) δ=2.30 (3H, s), 2.70 (3H, s), 3.83 (9H, s), 7.21 (2H, s), and 7.47 (1H, s). Found: C, 51.71; H, 6.00; S, 20.80%. Calcd for $C_{13}H_{18}O_4S_2$: C, 51.92; H, 6.00; S, 21.20%.

*Decomposition of 2-(3,4,5-Trimethoxyphenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**24**) with HCl.* *(a) 1 M Ethanolic Solution of HCl*: To a solution of **24** (502 mg) in ethanol (9 ml), was added a saturated ethanolic solution (1 ml) of HCl and then the resulting solution was refluxed for 1.5 h. After evaporation *in vacuo*, the residue was column-chromatographed on silica gel (benzene) to give ethyl (3,4,5-trimethoxyphenyl)acetate (248 mg) as a pale yellow oil and a mixture (98 mg) which was shown to consist of ethyl (3,4,5-trimethoxyphenyl)acetate and an unknown compound in the ratio of 3:2. This unknown compound exhibits NMR signals in $CDCl_3$ at δ=1.25 (3H, t, J=7 Hz), 2.06 (3H, s), 3.81 (9H, s), 4.11 (2H, q, J=7 Hz), 4.38 (1H, s), and 6.67 (2H, s), and it was deduced to be ethyl (3,4,5-trimethoxyphenyl)(methylthio)acetate. Therefore, the total yield of ethyl (3,4,5-trimethoxyphenyl)acetate was calculated to be 72%. An analytical sample was obtained by further column-chromatography and short-path distillation (bath temperature 150 °C/0.09 Torr): IR (neat) 1737 cm^{-1}; NMR ($CDCl_3$) δ=1.23 (3H, t, J=7 Hz), 3.48 (2H, s), 3.78 (9H, s), 4.11 (2H, q, J=7 Hz), and 6.46 (2H, s); MS (70 eV), *m/e* (relative intensity), 254 (M^+, 75), 181 (100), 167 (28), and 29 (33). Found: C, 61.31; H, 7.15%. Calcd for $C_{13}H_{18}O_5$: C, 61.41; H, 7.13%.

(b) In Saturated Ethanolic Solution of HCl: A saturated ethanolic solution (10 ml) of HCl was added to **24** (495 mg) and the resulting mixture was stirred at room temperature for 1.5 h. After evaporation *in vacuo*, the residue was column-chromatographed on silica gel (benzene) to give ethyl (3,4,5-trimethoxyphenyl)acetate (34 mg) as a yellow oil and a mixture (111 mg) which was shown by an NMR analysis to consist of ethyl (3,4,5-trimethoxyphenyl)acetate and ethyl (3,4,5-trimethoxyphenyl)(methylthio)acetate in the ratio of 42:35. The yield of the ethyl (3,4,5-trimethoxyphenyl)-acetate was calculated to be 62%.

Condensation of p-*Chlorobenzaldehyde with* **1**. *(a) Triton B in Dioxane*: To a solution containing **1** (1.17 g) and *p*-chlorobenzaldehyde (1.33 g) in dioxane (7 ml), was added a 40% methanolic solution (1 ml) of Triton B and the mixture was stirred at 80 °C for 25 h. After the addition of dichloromethane (100 ml), the resulting mixture was washed with *ca.* 2 M hydrochloric acid (10.5 ml), dried (Na_2SO_4), and evaporated *in vacuo*. The residue was column-chromatographed on silica gel (dichloromethane) to give 2-(*p*-chlorophenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**25**; 1.19 g: 51% yield) as a colorless oil: IR (neat) 1062 cm^{-1}; NMR (CCl_4) δ=2.32 (3H, s), 2.68 (3H, s), 7.36 (2H, d, J=8.7 Hz), 7.48 (1H, s), and 7.82 (2H, d, J=8.7 Hz). Found: C, 48.63; H, 4.81%. Calcd for $C_{10}H_{12}OS_2Cl$: C, 48.67; H, 4.49%.

Since **1** (354 mg) was recovered, the yield based on the consumed **1** was calculated to be 73%.

(b) Triton B in THF: To a solution containing *p*-chlorobenzaldehyde (501 mg) and **1** (445 mg) in THF (5 ml), was added a 40% methanolic solution (0.5 ml) of Triton B, the resulting mixture was refluxed for 6 h. After the addition of dichloromethane (30 ml), the mixture was washed with 0.5 M sulfuric acid (10 ml) and water (30 ml×2), dried (Na_2SO_4), and evaporated *in vacuo*. By column-chromatography on silica gel [dichloromethane–ethyl acetate (3:1)], **25** (574 mg: 65% yield) was given as a yellow oil.

(c) NaOH and Excess of **1**: After a mixture of **1** (8.83 g) and powdered sodium hydroxide (0.46 g) was stirred at 70 °C for 30 min, *p*-chlorobenzaldehyde (4.99 g) was added and the resulting mixture was further stirred at 70 °C for 1 h. After the addition of dichloromethane (100 ml) followed by being washed with 0.5 M sulfuric acid (20 ml) and water (100 ml×3), the organic layer was dried (Na_2SO_4) and evaporated *in vacuo*. The residue was column-chromatographed on silica gel (dichloromethane) to afford **25** (6.118 g: 70% yield) as a pale yellow oil.

*Decomposition of 2-(*p*-Chlorophenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**25**) with HCl.* *(a) In a Saturated Ethanolic Solution of HCl*: A solution containing **25** (260 mg) was saturated with HCl gas under ice-cooling. The reaction mixture was allowed to stand at room temperature overnight. Evaporation *in vacuo*, followed by column-chromatography on silica gel [benzene–hexane (1:1)], gave ethyl (*p*-chlorophenyl)acetate (193 mg: 92% yield) which was identified by the comparison of its IR spectrum with that of the authentic sample prepared by the usual esterification (HCl–ethanol) of commercially available (*p*-chlorophenyl)acetic acid.

(b) In Saturated Methanolic Solution of HCl: After a solution of **25** (517 mg) in methanol (6 ml) was saturated with HCl under cooling with ice-water, the resulting solution was stirred at room temperature for 2.5 h. After evaporation *in vacuo*, the residue was column-chromatographed on silica gel [benzene–hexane (1:4)] to give methyl (*p*-chlorophenyl)-acetate (303 mg: 78% yield) as a colorless oil which was identified by the comparison of its IR and NMR spectra with those of the authentic sample prepared by the usual esterification (HCl–methanol) of (*p*-chlorophenyl)acetic acid.

(c) In 1-Butanol: After a solution of **25** (538 mg) in 1-butanol (5 ml) was saturated with HCl under cooling with ice-water, the resulting solution was stirred at room temperature for 2.5 h. Evaporation *in vacuo*, followed by column-chromatography on silica gel [benzene–hexane (1:4)], afforded butyl (*p*-chlorophenyl)acetate (396 mg: 80% yield) as a colorless oil: IR (neat) 1740 cm^{-1}; NMR ($CDCl_3$) δ= 0.8—1.8 (7H, m), 3.45 (2H, s), 3.99 (2H, t, J=7 Hz), and 7.19 (4H, s). Found: C, 63.80; H, 6.41%. Calcd for $C_{12}H_{15}O_2Cl$: C, 63.57; H, 6.67%.

Condensation of o-*Bromobenzaldehyde with* **1**. To a solution of **1** (7.01 g) and *o*-bromobenzaldehyde (9.99 g) in THF (50 ml), was added a 40% methanolic solution (4 ml) of Triton B and the resulting mixture was refluxed for 46 h. After the addition of dichloromethane (100 ml), the mixture was washed with 0.5 M sulfuric acid (20 ml), dried (Na_2SO_4), and evaporated *in vacuo*. The residue was subjected to column-chromatography on silica gel (dichloromethane and

ethyl acetate) to give 2-(*o*-bromophenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**26**; 8.026 g: 51% yield) as a pale yellow oil: bp 167—170 °C/0.15—0.2 Torr; IR (neat) 1056 cm^{-1}; NMR ($CDCl_3$) δ=2.32 (3H, s), 2.77 (3H, s), 7.0—7.8 (4H, m) and 7.98 (1H, diffused s). Found: C, 41.08; H, 3.76%. Calcd for $C_{10}H_{11}S_2OBr$: C, 41.24; H, 3.81%.

*Decomposition of 2-(o-Bromophenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**26**) with HCl.* To a solution of **26** (505 mg) in ethanol (4.5 ml), was added a saturated ethanolic solution (0.5 ml) of HCl and the resulting solution was refluxed for 3 h. After evaporation *in vacuo*, the residue was column-chromatographed on silica gel and elution with hexane–benzene (9:1) gave ethyl (*o*-bromophenyl)acetate (390 mg: 92% yield) as a colorless oil: bp 75—80 °C/0.1 Torr; IR (neat) 1737 cm^{-1}; NMR ($CDCl_3$) δ=1.20 (3H, t, J=7 Hz), 3.49 (2H, s), 4.08 (2H, q, J=7 Hz), and 7.00—7.42 (4H, m). Found: C, 49.25; H, 4.53; Br, 33.06%. Calcd for $C_{10}H_{11}O_2Br$: C, 49.41; H, 4.56; Br, 32.87%.

Condensation of p-*Isopropylbenzaldehyde with **1**. (a) Triton B in THF*: To a solution of **1** (2.24 g) and *p*-isopropylbenzaldehyde (2.65 g) in THF (30 ml), was added a 40% methanolic solution (2 ml) of Triton B and the resulting solution was refluxed for 25 h. After the addition of dichloromethane (50 ml) and being washed with 1.5 M sulfuric acid (20 ml), the organic layer was dried (K_2CO_3) and evaporated *in vacuo*. The residue was column-chromatographed on silica gel (dichloromethane) to give 2-(*p*-isopropylphenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**27**; 3.013 g: 68% yield) as a pale yellow oil: bp 170—172 °C/0.2 Torr; IR (neat) 1063 cm^{-1}; NMR ($CDCl_3$) δ=1.25 (6H, d, J=7 Hz), 2.28 (3H, s), 2.70 (3H, s), 2.89 (1H, septet, J=7 Hz), 7.32 (2H, d, J=7 Hz), 7.57 (1H, s), and 7.81 (2H, d, J=7 Hz). Found: C, 61.24; H, 7.14; S, 24.95%. Calcd for $C_{13}H_{18}OS_2$: C, 61.38; H, 7.13; S, 25.20%.

*(b) NaOH and Excess of **1***: To a mixture of **1** (12.6 g) and powdered sodium hydroxide (1.35 g), was added *p*-isopropylbenzaldehyde (10.1 g) dropwise over 20 min under being stirred at 60 °C, and the resulting mixture was further stirred at 60 °C for 5 h. After dichloromethane (100 ml) was added, the mixture was washed with 0.5 M sulfuric acid (25 ml) and water (100 ml×2). The organic layer was dried (Na_2SO_4), evaporated *in vacuo*, and column-chromatographed on silica gel [benzene–dichloromethane (3:1)] to give **27** (14.45 g: 83% yield) as a yellow oil.

*Decomposition of 2-(p-Isopropylphenyl)-1-(methylsulfinyl)-1-(methylthio)ethylene (**27**) with HCl.* To a solution of **27** (1.01 g) in ethanol (9 ml), was added a saturated ethanolic solution of HCl and the solution was refluxed for 3 h. After evaporation *in vacuo*, the residue was column-chromatographed on silica gel (hexane) to give ethyl (*p*-isopropylphenyl)-acetate (789 mg: 96% yield) as a colorless oil. An analytical sample was obtained by a short-path distillation (bath temperature 110—115 °C/0.3 Torr): IR (neat) 1738 cm^{-1}; NMR ($CDCl_3$) δ=1.20 (3H, t, J=7 Hz), 1.20 (6H, d, J=7 Hz), 2.83 (1H, septet, J=7 Hz), 3.50 (2H, s), 4.08 (2H, q, J=7 Hz), and 7.12 (4H, s). Found: C, 75.52; H, 8.81%. Calcd for $C_{13}H_{18}O_2$: C, 75.69; H, 8.80%.

*Condensation of 2-Thiophenecarbaldehyde with **1**. (a) Triton B in THF*: To a solution containing 2-thiophenecarbaldehyde (10.315 g) and **1** (11.42 g) in THF (50 ml), was added a 40% methanolic solution (3 ml) of Triton B and then the resulting mixture was refluxed for 6 h. After the addition of dichloromethane (100 ml), the mixture was washed with 0.5 M sulfuric acid, dried (Na_2SO_4) and evaporated *in vacuo*. The residue was distilled *in vacuo* to afford **17** (17.31 g: 86% yield) as a pale yellow oil: bp 147—152 °C/0.11—0.13 Torr; IR (neat) 1055 and 710 cm^{-1}; NMR ($CDCl_3$) δ=2.35 (3H, s), 2.70 (3H, s), 7.05 (1H, m), 7.40 (2H, m), and 7.86 (1H, s). Found: C, 43.81; H, 4.83; S, 44.00%. Calcd for $C_8H_{10}OS_3$: C, 44.00; H, 4.62; S, 44.06%.

(b) KOH in Methanol: After 2-thiophenecarbaldehyde (1.043 g) and **1** (1.221 g) were dissolved in methanol (15 ml), potassium hydroxide (440 mg) was added and the resulting solution was refluxed for 24 h. The solution was evaporated *in vacuo* and dichrolomethane (100 ml) was added. The deposited insoluble matter was filtered off and the filtrate was evaporated *in vacuo*. The residue was separated by column-chromatography on silica gel (dichloromethane) to afford **17** (1.689 g: 83% yield) as a pale yellow oil.

*Decomposition of **17** with HCl. (a) At Room Temperature*: To a solution of **17** (872 mg) in ethanol (10 ml), was added a saturated ethanolic solution (1 ml) of HCl and the resulting solution was stirred under ice-cooling for 2 h and then at room temperature for 66 h. The solution was evaporated *in vacuo* and separated by column-chromatography on silica gel [hexane–benzene (1:1)] to give ethyl (2-thienyl)acetate (544 mg: 80% yield) as a pale yellow oil. This ester was identified with the authentic sample prepared by the usual esterification (HCl–ethanol) of (2-thienyl)acetic acid.

(b) Under Refluxing: To a solution of **17** (1.762 g) in ethanol (30 ml), was added a saturated ethanolic solution (2 ml) of HCl and the solution was refluxed for 22.5 h. After evaporation *in vacuo*, the residue was column-chromatographed on silica gel [benzene–hexane (1:1)] to give a pale yellow oil (1.172 g) which was shown by an NMR analysis to consist of ethyl (2-thienyl)acetate (1.039 g: 79% yield) and ethyl (methylthio)(2-thienyl)acetate (133 mg: 8% yield).[19]

Condensation of p-*Chlorobenzaldehyde with Phenyl (Phenylthio)-methyl Sulfoxide.* To a solution containing *p*-chlorobenzaldehyde (446 mg) and phenyl (phenylthio)methyl sulfoxide[3] (545 mg) in THF (5 ml), was added a 40% methanolic solution (0.5 ml) of Triton B and the mixture was refluxed for 5.5 h. After the addition of dichloromethane (100 ml), the mixture was washed with 0.5 M sulfuric acid, dried (Na_2SO_4), and evaporated *in vacuo*. The residue was separated by column-chromatography on silica gel (dichloromethane) to give 2-(*p*-chlorophenyl)-1-(phenylsulfinyl)-1-(phenylthio)-ethylene (**28**; 708 mg: 60% yield) as colorless crystals: mp 97.5—98.5 °C; IR (KBr) 1042 cm^{-1}: NMR (CCl_4) δ=7.06 (5H, s), 7.15—7.80 (9H, m), and 7.98 (1H, s). Found: C, 64.36; H, 3.85; S, 17.47%. Calcd for $C_{20}H_{15}OS_2Cl$: C, 64.76; H, 4.08; S, 17.29%.

*Decomposition of 2-(p-Chlorophenyl)-1-(phenylsulfinyl)-1-(phenylthio)ethylene (**28**) with HCl.* A solution containing **28** (180 mg) in ethanol (10 ml) was saturated with HCl gas under ice-cooling. The reaction mixture was allowed to stand overnight at room temperature, and then evaporated *in vacuo*. The residue was separated by column-chromatography on silica gel (hexane and benzene) to give diphenyl disulfide (94 mg: 89% yield) and ethyl (*p*-chlorophenyl)-acetate (82 mg: 90% yield).

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