The Claisen Rearrangement of the Lithium Enolate of 1-(2-Thienyl)alkyl Alkanoate and the Birch Reduction of the Resulting 2-(3-Thienyl)alkanoic Acid

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It was found that the Claisen rearrangement of the lithium enolate of 1-(2-thienyl)alkyl alkanoate in refluxing THF resulted in the formation of 2-(3-thienyl)alkanoic acid (**2**). Similarly, when the lithium enolate of 4-(2-thienyl)-4-butanolide was stirred at room temperature in the presence of hexamethylphosphoric triamide, 5,6-dihydro-4*H*-cyclopenta[*b*]thiophene-4-carboxylic acid was obtained. Further, it was found that the Birch reduction of **2** and subsequent alkylation with benzyl bromide gave a regioselective ring-opening product, 4-benzylthio-3-ethyl-3-alkenoic acid, in a good yield. The Birch reduction of 2-thienylacetic acid, followed by alkylation with benzyl bromide, also gave (*Z*)-3-benzylthio-3-hexenoic acid as the main product.

The Claisen rearrangement is an important and useful synthetic reaction, however, there has been few report,[1] of successfully obtaining 3-substituted thiophene derivatives starting from 1-(2-thienyl)-1-alkanol derivatives by the use of the Claisen rearrangement because of the formation of [1,3] sigmatropic rearrangement products.[2]

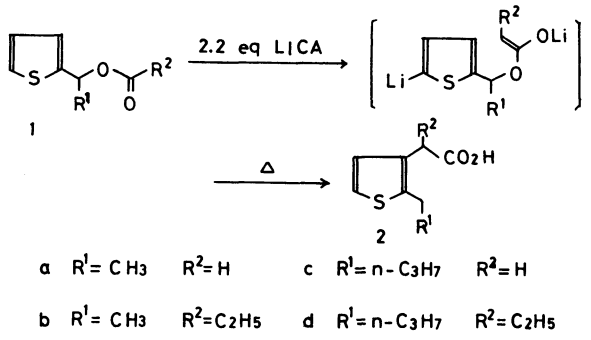
During the course of our investigation of the synthetic methodology which utilized thiophene derivatives as the key substances,[3] we needed a convenient method for the preparation of 3-substituted thiophenes. In this investigation, it was found that the Claisen rearrangement of the lithium enolate[4] of 1-(2-thienyl)alkyl alkanoate (**1**) successfully gave 2-(3-thienyl)alkanoic acid (**2**). Further, regioselective ring-opening products, 4-benzylthio-3-ethyl-3-alkenoic acids, were obtained by the Birch reduction of **2** and subsequent alkylation with benzyl bromide.

Results and Discussion

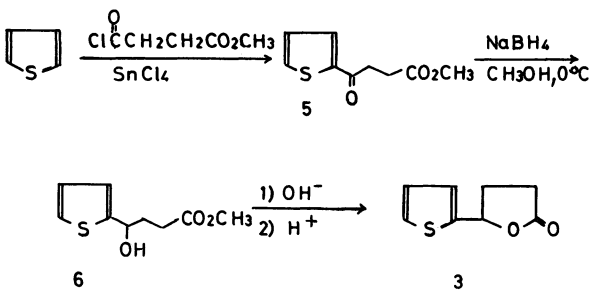
The Claisen Rearrangement of 1. It was found that, when **1a—d** were treated with 2.2 equivalents of lithium *N*-isopropylcyclohexylamide (LICA) at −70 °C in THF under nitrogen and the resulting lithium enolates were subsequently refluxed in THF, **2a—d** were obtained. (See Table 1).

As in shown in Table 1, the reaction of an equimolar amount of LICA with **1a** did not give the rearrangement product because of the formation of lithium salt at the 5-position of the thiophene nuclei (Run 1). Further, when butyryl derivatives, **1b**, **d**, were used as starting materials, rearrangement products, **2b**, **d**, were obtained in rather better yields than in the rearrangement of acetyl derivatives, **1a**, **c**.

Next, we investigated the rearrangement of 4-(2-thienyl)-4-butanolide (**3**) to form the corresponding cyclopentanecarboxylic acid derivative (**4**).



The preparation of **3** was carried out as in the following Scheme, the yields of **5**, **6**, and **3** were 91, 96, and 85% respectively.



Scheme 1.

As in shown in Table 2, when **3** was treated with LICA under reaction conditions similar to these in the rearrangement of **1**, the expected rearrangement product, **4**, was not obtained, but **3** was recovered

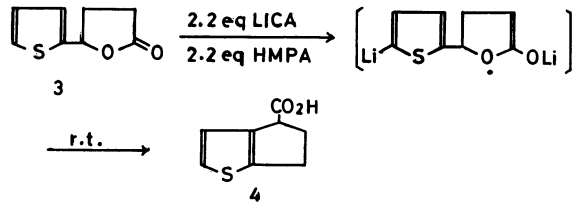
Table 1. Claisen rearrangement of the lithium enolate of 1-(2-thienyl)alkyl alkanoate (**1**)

Run	R^1	R^2	Reaction conditions: LICA(eq)	Reaction conditions: Temp/°C (Time/h)	Yield/% of **2**
1	CH_3	H	1.2	−78(1)→50(5)	—
2	CH_3	H	2.2	−78(1)→66(3)	38
3	CH_3	C_2H_5	2.2	−78(1)→66(5)	82
4	*n*-C_3H_7	H	2.2	−78(1)→66(3)	30
5	*n*-C_3H_7	C_2H_5	2.2	−78(1)→66(3)	81

Table 2. Claisen rearrangement of the lithium enolate of 4-(2-thienyl)-4-butanolide (3)

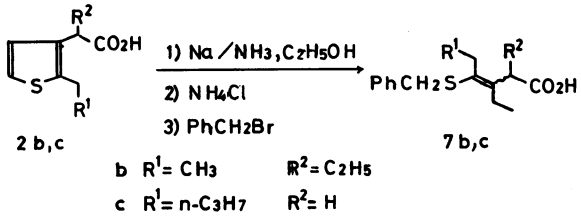
Run	Reaction conditions				Yield/% of 4
	Solvent	HMPA(eq)	Temp	Time/h	
1	THF	—	Reflux	3	—
2	THF	2.2	Reflux	3	42
3	THF	2.2	rt	18	44
4	THF/HMPA 9 : 1		rt	12	22

completely. However, it was found that the reaction of **3** with 2.2 equivalents of LICA in the presence of 2.2 equivalents of hexamethylphosphoric triamide (HMPA) at −70 °C in THF, and subsequent stirring at room temperature for 18 h, resulted in the formation of **4** in a 44% yield.



The Birch Reduction of **2**. It is well known that the Birch reduction of thiophene derivatives results in the formation of many products. For example, the Birch reduction of thiophene gives 2,5- and 2,3-dihydrothiophenes and a mixture of ring-opening products, butenethiols.[5] However, in recent investigations, it has been reported that the Birch reduction of 2-acyl-[6] or 2-carboxythiophene[7] formed 2,5-dihydrothiophenes selectively. It has been also reported from our laboratory[3] that the selective formation of 2-acyl-2-alkyl-2,5-dihydrothiophene derivatives has been established by the Birch reduction of 2-acylthiophene and subsequent alkylation with alkyl halides. In the present investigation, it was found that a regioselective ring-opening reaction occurred by means of the Birch reduction of **2**.

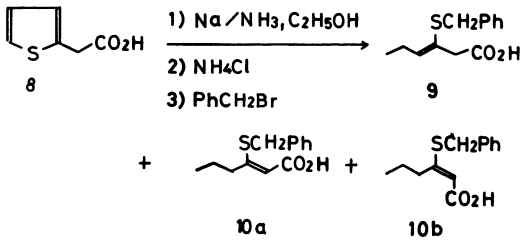
When **2b** was allowed to react with 5 equivalents of sodium in liquid ammonia in the presence of ethanol, and to the reaction mixture then were subsequently added 3 equivalents of ammonium chloride and benzyl bromide, 4-benzylthio-2,3-diethyl-3-hexenoic acid (**7b**) was obtained in a 72% yield. In a similar manner, the Birch reduction of **2c** and subsequent alkylation with benzyl bromide gave 4-benzylthio-3-ethyl-3-octenoic acid (**7c**) in an 82% yield.



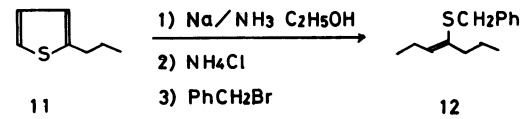
A regioselective ring-opening Birch reduction has been disclosed by Joullié *et al.*[7] It was reported there that the Birch reduction of 2-thiophenecarboxylic acid by 3 equivalents of lithium gave 2,5-dihydro-2-thiophenecarboxylic acid, while that by 5 equivalents of lithium gave (*Z*)-5-mercapto-3-pentenoic acid, which was formed regioselectively by reductive cleavage between the sulfur atom and the carbon atom at the 1-position of the thiophene ring. However, in our reaction, the reductive cleavage of the thiophene ring occurred between the sulfur atom and the carbon atom at the 5-position of thiophene ring regioselectively, while the double bond of the thiophene ring remained at the 1-position. Further, the reaction of **2b** with 3 equivalents of sodium and the subsequent addition of benzyl bromide resulted in the formation of **7b** in a 52% yield while the starting material, **2b**, was recovered in a 32% yield without any formation of dihydrothiophene derivatives. These results show that the regioselective ring-opening reaction occurred predominantly.

Next, the Birch reduction of 2-thienylacetic acid (**8**) was investigated under the assumption that the unusual ring-opening reaction would occurred as the effect of the carboxymethyl group.

When **8** was allowed to react with 5 equivalents of sodium in liquid ammonia, and to this mixture then were subsequently added 3 equivalents of ammonium chloride and benzyl bromide, similar type ring-opening product was obtained in an 84% yield. On the other hand, this product contained (*Z*)-3-benzylthio-3-hexenoic acid (**9**) and the double bond isomerized products, (*Z*)- and (*E*)-3-benzylthio-2-hexenoic acid (**10a**, **b**), in the ratio of 84 : 12 : 4.



Further, it was found that the Birch reduction of 2-propylthiophene (**11**), which did not contain the carboxyl group, with 4 equivalents of sodium and subsequent alkylation with benzyl bromide also gave a regioselective ring-opening product, (*Z*)-4-benzylthio-3-heptene (**12**), in a 72% yield.



From these results, we could not make clear the reason for the specificity of reductive ring-opening reaction of thiophene derivatives, but we are continuing our investigation of the Birch reduction of many types of thiophene derivatives.

Experimental

Preparation of 1-(2-Thienyl)ethyl Acetate (1a). Into a solution of 1-(2-thienyl)ethanol (3.89 g, 30 mmol) in 20 ml of

dry dichloromethane and 20 ml of dry pyridine, acetyl chloride (2.2 ml, 31 mmol) was added at 0 °C with stirring. The stirring was continued for 2 h at 0 °C and then for additional 22 h at room temperature. The reaction mixture was acidified by 10% hydrochloric acid and extracted with dichloromethane. The dichloromethane layer was dried over sodium sulfate. After the removal of the solvent, the residue was chromatographed on silica gel, **1a** was obtained by the elution of benzene [5.05 g (98%)]. The **1a** was further purified by distillation; bp 93 °C (10 mmHg, 1 mmHg=133.32 Pa). IR (NaCl): 1735 cm^{-1} (C=O), 1230 cm^{-1} (-O-); NMR($CDCl_3$): δ=1.67 (3H, d), 2.08 (3H, s), 6.31 (1H, q), 7.03—7.22 (2H, m), 7.35—7.47 (1H, m); MS: *m/e* 170 (M^+).

Similarly, 1-(2-thienyl)ethyl butyrate (**1b**), 1-(2-thienyl)-butyl acetate (**1c**), and 1-(2-thienyl)butyl butyrate (**1d**) were prepared from the corresponding alcohols and acid chlorides. The spectral and analytical data of **1b**, **1c**, and **1d** are as follows:

1b: Yield 92%, bp 82—85 °C (2.5 mmHg); IR(NaCl): 1730 cm^{-1} (C=O), 1165 cm^{-1} (-O-); NMR($CDCl_3$): δ=0.95 (3H, t), 1.42—2.00 (5H, m), 2.35 (2H, t), 6.35 (1H, q), 7.03—7.25 (2H, m), 7.36—7.47 (1H, m); MS: *m/e* 198 (M^+). Found: C, 60.51; H, 7.18%. Calcd for $C_{10}H_{14}O_2S$: C, 60.56; H, 7.23%.

1c: Yield, 98%, bp 74—75 °C (2 mmHg); IR(NaCl): 1730 cm^{-1} (C=O), 1220 cm^{-1} (-O-); NMR($CDCl_3$): δ=0.95 (3H, t), 1.22—2.03 (4H, m), 2.02 (3H, s), 6.16 (1H, t), 6.95—7.18 (2H, m), 7.27—7.38 (1H, m); MS: *m/e* 198 (M^+). Found: C, 60.56; H, 7.23%. Calcd for $C_{10}H_{14}O_2S$: C, 60.59; H, 7.12%.

1d: Yield, 94%. The **1d** was used for the next reaction without distillation. An oily product; IR(NaCl): 1735 cm^{-1} (C=O), 1170 cm^{-1}, 1095 cm^{-1} (-O-); NMR($CDCl_3$): δ= 0.78—1.03 (6H, m), 1.17—2.03 (6H, m), 2.28 (2H, t), 6.05 (1H, t), 6.82—7.30 (3H, m); MS: *m/e* 226 (M^+). Found: C, 63.45; H, 7.95%. Calcd for $C_{12}H_{18}O_2S$: C, 63.70; H, 8.02%.

The Claisen Rearrangement of Lithium Enolate of 1a. To a solution of lithium *N*-isopropylcyclohexylamide, prepared from *N*-isopropylcyclohexylamine (1.56 g, 11 mmol) and butyllithium (11 mmol) in THF (13 ml), a solution of **1a** (0.850 g, 5 mmol) in THF (13 ml) was added at −78 °C under nitrogen. The reaction mixture was stirred at −78 °C for 1 h and then refluxed for 3 h with stirring. After the addition of a 5% potassium hydroxide solution, the mixture was extracted with diethyl ether. The water layer was acidified with concentrated hydrochloric acid and extracted with dichloromethane. The dichloromethane layer was dried over sodium sulfate, and the solvent was removed under reduced pressure. After the residue has been chromatographed on silica gel, (2-ethyl-3-thienyl)acetic acid (**2a**) was obtained as an oily product from the elution of benzene–diethyl ether (4 : 1) [0.329 g (38%)]. IR(NaCl): 3200—2560 cm^{-1} (CO_2H), 1705 cm^{-1} (C=O); NMR($CDCl_3$): δ=1.28 (3H, t), 2.82 (2H, q), 3.62 (2H, s), 6.97—7.30 (2H, m), 12.15 (1H, s); MS: *m/e* 170 (M^+). Found: C, 56.34; H, 5.77%. Calcd for $C_8H_{10}O_2S$: C, 56.46; H, 5.92%.

Further, the structure of the **2a** was established by reductive desulfurization with Raney nickel.[8] The reaction of **2a** (0.319 g, 2 mmol) with Raney nickel, prepared from 20 g of the nickel–aluminum alloy, in refluxing 95% ethanol (100 ml) for 12 h gave a known carboxylic acid,[9] 3-ethylhexanoic acid [0.103 g (38%)]. IR(NaCl): 3400—2300 cm^{-1} (CO_2H), 1705 cm^{-1} (C=O); NMR($CDCl_3$): δ=0.80—1.13 (6H, m), 1.33—1.56 (7H, m), 2.30 (2H, t), 11.06 (1H, s); MS: *m/e* 144 (M^+).

In a similar procedure, the rearrangement of **1b**, **1c**, and **1d** was performed, 2-(2-ethyl-3-thienyl)butyric acid (**2b**), 2-(2-butyl-3-thienyl)acetic acid (**2c**), and 2-(2-butyl-3-thienyl)-butyric acid (**2d**) respectively were thus obtained. The spectral and analytical data are as follows: **2b**: Bp 139—140 °C (4 mmHg); IR(NaCl): 3200—2550 cm^{-1} (CO_2H), 1700 cm^{-1} (C=O); NMR($CDCl_3$): δ=0.90 (3H, t), 1.29 (3H, t), 1.65—2.28 (2H, m), 2.88 (2H, q), 3.67 (1H, t), 7.15 (2H, m), 11.92 (1H, s); MS: *m/e* 198 (M^+). Found: C, 60.78; H, 6.84%. Calcd for $C_{10}H_{14}O_2S$: C, 60.59; H, 7.12%.

2c: An oily product; IR(NaCl): 3200—2550 cm^{-1} (CO_2H), 1700 cm^{-1} (C=O); NMR($CDCl_3$): δ=0.95 (3H, t), 1.25—1.80 (4H, m), 2.63—2.93 (2H, m), 3.63 (2H, s), 6.98—7.25 (2H, m), 12.08 (1H, s); MS: *m/e* 198 (M^+). Found: C, 60.50; H, 7.16%. Calcd for $C_{10}H_{14}O_2S$: C, 60.95; H, 7.12%.

2d: An oily product; IR(NaCl): 3100—2530 cm^{-1} (CO_2H), 1700 cm^{-1} (C=O); NMR($CDCl_3$): δ=0.78—1.03 (6H, m), 1.23—2.27 (6H, m), 2.87 (2H, t), 3.67 (1H, t), 7.07—7.28 (2H, m), 12.11 (1H, s); MS: *m/e* 226 (M^+). Found: C, 63.70; H, 7.83%. Calcd for $C_{12}H_{18}O_2S$: C, 63.70; H, 8.02%.

Preparation of 4-(2-Thienyl)-4-butanolide (3). Methyl 4-oxo-4-(2-thienyl)butyrate (**5**) was prepared from thiophene (8.44 g, 0.1 mol) and methyl 3-(chloroformyl)propionate (15.07 g, 0.1 mol) by the use of the Friedel-Crafts reaction[10] [18.03 g (91%), bp 125—127 °C (2 mmHg)]; IR(NaCl): 1730 cm^{-1}, 1660 cm^{-1} (C=O), 1215 cm^{-1}, 1160 cm^{-1} (-O-); NMR ($CDCl_3$): δ=2.72 (2H, t), 3.24 (2H, t), 3.63 (3H, s), 6.97—7.10 (1H, m), 7.50—7.73 (2H, m); MS: *m/e* 198 (M^+). Found: C, 54.81; H, 5.05%. Calcd for $C_9H_{10}O_3S$: C, 54.54; H. 5.09%.

To a solution of **5** (4.02 g, 20 mmol) in 30 ml of methanol, sodium borohydride (0.391 g, 10 mmol) was added in small portions at 0 °C. After stirring for 1 h at 0 °C, to the reaction mixture we added 1.4 ml of acetic acid and 100 ml of water. The mixture was then extracted with diethyl ether, and the ether layer was washed with a saturated solution of sodium hydrogencarbonate and dried over sodium sulfate. After the removal of the solvent, the residue was chromatographed on silica gel and methyl 4-hydroxy-4-(2-thienyl)butyrate (**6**) was obtained from the elution of benzene and diethyl ether (1 : 1) [3.88 g (96%), an oily product]. IR(NaCl): 3440 cm^{-1} (OH), 1720 cm^{-1} (C=O); NMR($CDCl_3$): δ=1.87—2.60 (4H, m), 3.47 (1H, brs), 3.60 (3H, s), 4.92 (1H, q), 6.77—7.00 (1H, m), 7.12—7.30 (1H, m); MS: *m/e* 200 (M^+). Found: C, 54.00; H, 6.05%. Calcd for $C_9H_{12}O_3S$: C, 53.99; H, 6.04%.

A mixture of **6** (2.02 g, 10 mmol) and sodium hydroxide (0.49 g, 12 mmol) in 10 ml of water and 5 ml of methanol was stirred at room temperature for 0.5 h. The methanol was then removed under reduced pressure and concentrated hydrochloric acid (3 ml) was added to the residue. After the the mixture has been stirred for 2 h at room temperature, 20 ml of water was added and the mixture was extracted with diethyl ether. The ether layer was dried over sodium sulfate. The solvent was removed by distillation, and the residue was chromatographed on silica gel. From the elution of benzene and diethyl ether (3 : 1), 4-(2-thienyl)-4-butanolide (**3**) was obtained as an oily product [1.44 g (85%)]. The **3** was further purified by distillation under reduced pressure [bp 153 °C (5 mmHg)]; IR(NaCl): 1770 cm^{-1} (C=O), 1200 cm^{-1}, 1120 cm^{-1} (-O-); NMR($CDCl_3$): δ=2.30—2.87 (4H, m), 5.68 (1H, t), 6.85—7.03 (2H, m), 7.19—7.32 (1H, m); MS: *m/e* 168 (M^+). Found: C, 57.18; H, 4.78%. Calcd for $C_8H_8O_2S$: C, 57.14; H, 4.80%.

The Claisen Rearrangement of the Lithium Enolate of 3. Into a solution of lithium *N*-isopropylcyclohexylamide, prepared from *N*-isopropylcyclohexylamine (1.555 g, 11 mmol) and butyllithium (11 mmol), and hexamethylphosphoric triamide (1.978 g, 11 mmol) in 25 ml of THF, a solution of **3** (0.843 g, 5 mmol) in 8 ml of THF was added at −78 °C with stirring

under nitrogen. After the temperature has then been elevated to room temperature, the reaction mixture was stirred for 18 h. After the addition of 10% hydrochloric acid, the mixture was extracted with diethyl ether. The ether layer was dried over sodium sulfate and the solvent was removed under reduced pressure. When the residue was chromatographed on silica gel, 5,6-dihydro-4*H*-cyclopenta[*b*]thiophene-4-carboxylic acid (**4**) was obtained as a solid product by the elution of dichloromethane [0.368 g (44%)]; mp 52—53 °C; IR(KBr): 3100—2550 cm^{-1} (CO_2H), 1690 cm^{-1} (C=O); NMR($CDCl_3$): δ= 1.20—2.10 (4H, m), 2.63—2.95 (1H, m), 6.80—7.18 (2H, m), 11.65 (1H, s); MS: *m/e* 168 (M^+). Found: C, 57.05; H, 4.90%. Calcd for $C_8H_8O_2S$: C, 57.14; H, 4.80%.

*The Birch Reduction of **2b**, Followed by Benzylation.* To a mixture of **2b** (0.834 g, 4.2 mmol), 1.5 ml of dry diethyl ether, 1.5 ml of absolute ethanol, and 25 ml of liquid ammonia, small pieces of sodium (0.519 g, 22.6 mmol) were added over the period of 1 h under reflux. After the mixture then been stirred for 1 h in refluxing liquid ammonia, a solid of ammonium chloride (0.721 g, 13.5 mmol) was added and the mixture was stirred for 0.5 h. Next, benzyl bromide (0.6 ml, 5 mmol) was added to the mixture, and the mixture was stirred for 20 min. Further, additional benzyl bromide (0.6 ml, 5 mmol) was added into the mixture, and the mixture was stirred for 1 h with refluxing. The ammonia was then evaporated, and the residue we added 10 ml of 10% hydrochloric acid and 10 ml of chloroform. The mixture was stirred for 1 h, and then the chloroform layer was separated. The chloroform layer was washed with water and dried over sodium sulfate. After the removal of the solvent, the residue was chromatographed on silica gel. From the elution of benzene–diethyl ether (10 : 1), 4-benzylthio-2,3-diethyl-3-hexenoic acid (**7b**) was obtained as an oily product [0.888 g (72%)]. IR(NaCl): 3080—2600 cm^{-1} (CO_2H), 1700 cm^{-1} (C=O); NMR($CDCl_3$): δ=0.68—2.57 (15H, m), 3.43 (1H, t), 3.80 (2H, s), 7.25 (5H, s), 11.32. (1H, s); MS: *m/e* 292 (M^+). Found: C, 69.78; H, 8.29% Calcd for $C_{17}H_{24}O_2S$: C, 69.83; H, 8.27%.

In a similar procedure, the Birch reduction and subsequent benzylation of **2c** and 2-thienylacetic acid (**8**) were performed. The yield and spectral data of products are as follows: 4-Benzylthio-3-ethyl-3-octenoic acid (**7c**): Yield, 82%; an oily product; IR(NaCl): 3050—2550 cm^{-1} (CO_2H), 1700 cm^{-1} (C=O); NMR($CDCl_3$): δ=0.73—1.13 (6H, m), 1.27—1.82 (4H, m), 2.23—2.62 (4H, m), 3.25 (2H, s), 3.92 (2H, s), 7.43 (5H, s), 12.08 (1H, s); MS: *m/e* 292 (M^+). Found: C, 70.08; H, 8.32%. Calcd for $C_{17}H_{24}O_2S$: C, 69.83; H, 8.27%.

(E)-3-Benzylthio-3-hexenoic acid (**9**): Yield, 71%; mp 92.5—94 °C (from petroleum ether); IR(KBr): 3100—2550 cm^{-1} (CO_2H), 1710 cm^{-1} (C=O); NMR($CDCl_3$): δ=0.87 (3H, t), 2.23 (2H, quen), 3.27 (2H, s), 3.89 (2H, s), 5.90 (1H, t), 7.32 (5H, m), 11.45 (1H, s); MS: *m/e* 236 (M^+). Found: C, 66.37; H, 6.78%. Calcd for $C_{13}H_{16}O_2S$: C, 66.08; H, 6.83%.

(Z)-3-Benzylthio-2-hexenoic acid (**10a**): Yield, 9%; mp 117.5—118.5 °C (from petroleum ether); IR(KBr): 3075—2550 cm^{-1} (CO_2H), 1680 cm^{-1} (C=O), 1580 cm^{-1} (C=C); NMR($CDCl_3$): δ=0.98 (3H, t), 1.30—1.87 (2H, m), 2.83 (2H, t), 4.03 (2H, s), 7.36 (5H, s), 11.55 (1H, s); MS: *m/e* 236 (M^+). Found: C, 65.71; H, 6.76%. Calcd for $C_{13}H_{16}O_2S$: C, 66.08; H, 6.83%.

(E)-3-Benzylthio-2-hexenoic acid (**10b**): Yield, 3%; mp 145—146 °C (from petroleum ether); IR(KBr): 3050—2500 cm^{-1} (CO_2H), 1655 cm^{-1} (C=O), 1555 cm^{-1} (C=C); NMR ($CDCl_3$): δ=1.00 (3H, t), 1.30—1.85 (2H, m), 2.53 (2H, t), 4.17 (2H, s), 5.93 (1H, s), 7.50 (5H, s); MS: *m/e* 236 (M^+). Found: C, 66.02; H, 6.83%. Calcd for $C_{13}H_{16}O_2S$: C, 66.08; H, 6.83%.

*The Birch Reduction of 2-Propylthiophene (**11**), Followed by Benzylation.* To a liquid ammonia solution (50 ml) of absolute ethanol (2.5 ml) and **11** (1.269 g, 10 mmol) dissolved in diethyl ether (2.5 ml) we added small pieces of sodium (0.926 g, 40 mmol) over a period of 1.5 h. After refluxing for 1 h, ammonium chloride (1.641 g, 31 mmol) was added to the mixture, and the mixture was stirred for 0.5 h. Next, benzyl bromide (1.5 ml, 12.5 mmol) was added to the mixture, and the mixture was stirred for 20 min. Further, additional benzyl bromide (1.5 ml, 12.5 mmol) was added to the mixture. The reaction mixture was then refluxed for 1 h. The ammonia was subsequently removed, and 10% hydrochloric acid was added to the residue. The mixture was extracted with diethyl ether, and the ether layer was dried over sodium sulfate. After the removal of the solvent, the residue was chromatographed on silica gel and (*Z*)-4-benzylthio-3-heptene (**12**) was obtained as an oily product from the elution of petroleum ether [1.646 g (74%)]. IR(NaCl): 1605 cm^{-1}, 1500 cm^{-1}, 1460 cm^{-1} (Ph); NMR($CDCl_3$): δ=0.73—0.99 (6H, m), 1.28—1.87 (2H, m), 2.28—2.43 (4H, m), 3.82 (2H, s), 5.68 (1H, t), 7.36 (5H, s); MS: *m/e* 220 (M^+). Found: C, 76.72; H, 9.06%. Calcd for $C_{14}H_{20}S$: C, 76.32; H, 9.15%.

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