Synthesis and Reactions of (*E*)- and (*Z*)-1,3-Dibromo-2-methoxypropene

Kjetil Røe Edvardsen and Tore Benneche*

Department of Chemistry, University of Oslo, P.O. Box 1033, Blindern, 0315 Oslo, Norway

Marcus A. Tius

Department of Chemistry, University of Hawaii at Manoa, 2545 The Mall, Honolulu, Hawaii 96822

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(*Z*)-1,3-Dibromo-2-methoxypropene is prepared in 90% yield by dehydrohalogenation of 1,2,3-tribromo-2-methoxypropane with diisopropylamine in dichloromethane. The *E*-isomer can be obtained as the only product in almost quantitative yield by UV irradiation of the *Z*-isomer. Nucleophilic displacement reactions of the allylic bromide and palladium-catalyzed coupling reactions of the vinylic bromide in (*E*)- and (*Z*)-1,3-dibromo-2-methoxypropene have been studied.

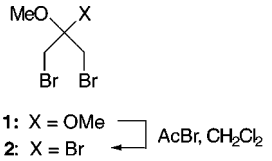
Introduction

Nucleophilic displacement reactions on 1,3-dihalo-2-propanones have been widely used to add a three-carbon unit to organic compounds.[1−9] We were interested in developing a 2-propanone derivative that could undergo nucleophilic displacement reactions at C-1 and palladium-catalyzed coupling reactions at C-3. The commercially available 1,3-dibromo-2-propanone was not considered to be a good candidate for these reactions, since dialkylation may be a problem with this compound[10] and anomalies have been observed in palladium-catalyzed coupling reactions with α-bromo ketones.[11]

Palladium(0) complexes react easily with vinyl and aryl halides, especially bromides and iodides.[12] *β*-Bromovinyl ethers can also be used in palladium-catalyzed reactions.[13] This indicated that the keto function in 2-propanone could be masked as an enol ether to get a suitable substrate for palladium-catalyzed reactions. Thus our target molecule would be a 1,3-dihalo-2-alkoxypropene. 1,3-Dibromo-2,2-dimethoxypropane **1**, which can be readily prepared in one step from acetone,[14] was an obvious candidate for the preparation of such an enol ether.

Results and Discussion

Treatment of compound **1** with a catalytic amount of *p*-toluenesulfonic acid in toluene at 200 °C, gave a 4:1 mixture of the (*E*)- and (*Z*)-1,3-dibromo-2-methoxypropene (**3a** and **3b**) in 50% yield. [Note: **3a** is (*Z*) and **3b** is (*E*)]. The relatively low *E*/*Z*-selectivity and yield in this reaction led us to consider the formation of **3** by dehydrobromination of **2** under basic conditions. Compound **2** was prepared in almost quantitative yield by reacting the acetal **1** with acetyl bromide in dichloromethane at ambient temperature.



A number of bases were examined for the dehydrohalogenation of **2**. Potassium *tert*-butoxide or potassium carbonate in DMF gave a nearly 1:1 mixture of **3a** and **3b** in moderate yields. With amines the yield varied from 0% to >90%. The reactions were in all cases unselective, except when diisopropylamine in dichloromethane was used. Then the ratio of the *Z*- and *E*-isomers was 93:7 (entry 4, Table 1). The isolated yield of the *Z*-isomer from the reaction was 90%.

Conducting the elimination at other temperatures, i.e., at 25 and −78 °C, had little effect on the product distribution, except in the case of diisopropylamine, which at 25 °C gave a lower selectivity (70:30 mixture of **3a**/**3b**) than at 0 °C. The reason diisopropylamine, in contrast to the other amines, gives good selectivity for the *Z*-isomer **3a**, as well as a good chemical yield, is unclear. The base strength of the amines in water does not correlate well with the yield of the elimination reaction (Table 1). *tert*-Butylamine, for instance, which has approximately the same pK_{BH} as diisopropylamine,

* Ph: +4722855556. Fax: +4722855441. E-mail: tore.benneche@kjemi.uio.no.

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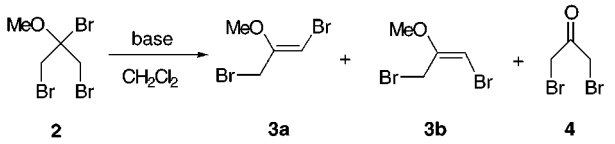
Table 1. Amine Bases in the Dehydrobromination of 2



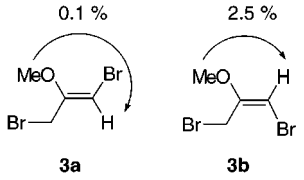
2 3a 3b 4

entry	base	pK_{BH}[b,c]	product distribution (%)[a] 3a	3b	4
1	2,6-lutidine	7.36	33	17	50
2	DMAP	9.68	0	0	100
3	*tert*-butylamine	10.95	7	3	90
4	diisopropylamine	10.96	93	7	0
5	ethyldiisopropylamine	11.51	35	35	30
6	DBU	14.30[d]	67	33	0

[a] From ^{1}H NMR of the crude product. [b] In H_2O. [c] For references, see Experimental Section. [d] Calculated.

gave only 10% elimination (entry 3, Table 1). Ethyldiisopropylamine, which is a stronger base than diisopropylamine, also gave less elimination than diisopropylamine (entry 5). The base strength seems to be of some importance, because weak bases such as 2,6-lutidine and DMAP gave low yields in the elimination while the strong and nonnucleophilic base DBU gave complete elimination (entries 1, 2, and 6). DMAP is a stronger base than 2,6-lutidine but gave no elimination. The reason may be that DMAP is acting like a nucleophile, giving a substitution product that is hydrolyzed to **4** during the workup.

The stereochemistry of the compounds **3a** and **3b** was determined by NOE.



3a 3b

The thermal stability of **3** was investigated by heating a 93:7 mixture of **3a** and **3b** from ambient temperature to 135 °C. The temperature was increased by 10 °C every 30 min, at which point samples were taken and analyzed by ^{1}H NMR. When the temperature had reached 100 °C the *Z*/*E*-ratio had changed to 75:25 without noticeable decomposition. Further heating led to decomposition without any change in the isomer ratio.

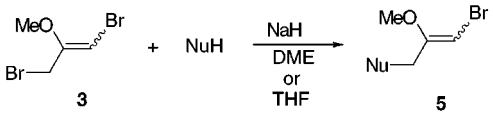
Irradiation of **3a** in hexane with a low-pressure UV lamp resulted in complete conversion of the *Z*-isomer to the *E*-isomer. The yield in the conversion was almost quantitative.

The elimination reaction with diisopropylamine gives access to nearly pure **3a**, and photoisomerization gave **3b**. With a convenient source of both geometrical isomers of **3**, the nucleophilic displacement reactions of the allylic bromide were examined.

Alkylation of oxygen nucleophiles (entries 1−4, Table 2) and active methylene compounds (entries 5 and 6) with **3** under basic conditions was successful. Double bond isomerization was observed only with the anion of benzyl alcohol (entry 4). Products from a S_N2' process could not be detected in the reaction mixture.

Alkenyl halides are useful substrates for the Sonogashira−Castro reaction.[15] The coupling of **5a** with

Table 2. Alkylations with 3a and 3b



3 5

entry	alkene	NuH	product	E/Z	yield (%)[a]
1	**3a**	C_6H_4OH	**5a**	*Z*	88
2	**3a**	2-I-C_6H_4OH	**5b**	*Z*	83
3	**3b**	2-I-C_6H_4OH	**5c**	*E*	83
4	**3a**	$PhCH_2OH$	**5d**	*Z*/*E*[b]	79
5	**3b**	diethyl malonate	**5e**	*E*	(82)[c]
6	**3b**	ethyl acetoacetate	**5f**	*E*	67

[a] Isolated. [b] *Z*/*E* ratio 5:1. [c] Crude product.

ethynyltrimethylsilane and 1-hexyne could be effected at ambient temperature under standard conditions (entries 1 and 2, Table 3). Compounds **5b** and **5c** [note: **5b** is (*Z*) and **5c** is (*E*)] were reacted with 1.1 equiv of 1-hexyne in the presence of palladium to determine if the aromatic iodide could be selectively substituted in the presence of a *β*-alkoxy alkenylic bromide. The *Z*-isomer **5b** gave a 4:1 mixture of the monoalkylated **7a** and the dialkylated product **8a** (entry 3, Table 3), whereas the *E*-isomer **5c** gave only the product from reaction at the aromatic iodide (entry 4). Since these reactions have been conducted under the same conditions, the results indicate that the vinylic bromide in the *Z*-isomer **5b** is more reactive than in the *E*-isomer **5c** in the Sonogashira−Castro reaction. Reaction of the *E*-isomer **5b** with an excess of alkyne gave the dialkylated product **8b** in good yield (entry 5). The diynes **8a** and **8b** should be well suited for further elaboration in the side chain.

The Heck reaction is one of the more impotant reactions in contemporary organic synthesis.[16] In this reaction the regeneration of the catalyst is normally achieved by a *β*-hydride elimination.[16] In some cases a *β*-substituent other than a hydride may be eliminated, e.g., a bromide[17] or a TMS group.[18] In the latter case the TMS group is eliminated in preference to a *β*-hydrogen. We wanted to investigate if **5b** could be cyclized in a Heck process. We assumed that the oxidative addition of palladium(0) would be more rapid to the iodide in the 2-position of the aromatic ring than to the vinylic bromide in the side chain. The coupling reaction of **5b** with 1-hexyne (vide supra) supports this view. If the reaction mechanism involved addition of an aromatic palladium complex to the double bond of the side chain, only a 6-endo-trig cyclization seemed resonable. The new palladium complex would then have the possibility for a *β*-hydride elimination or a *β*-bromide elimination. When **5b** was treated with palladium(0) under standard Heck conditions, only **9** was isolated (58% yield); no other elimination products were observed (Scheme 1). Reacting **5c** in the same way gave almost the same result (61% yield of **9**). The amine is possibly the stoichiometric reducing agent.

The effectiveness of the intramolecular Heck reaction of **5** to **9** was compared to an intermolecular Heck reaction.Treatment of **5b** and **5c** with methyl acrylate led in both cases to **9**, the product of intramolecular

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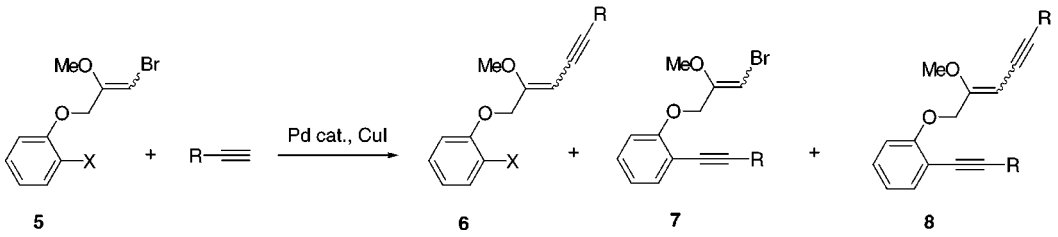
Table 3. Palladium-Catalyzed Coupling Reactions of Alkynes with 5a or 5b

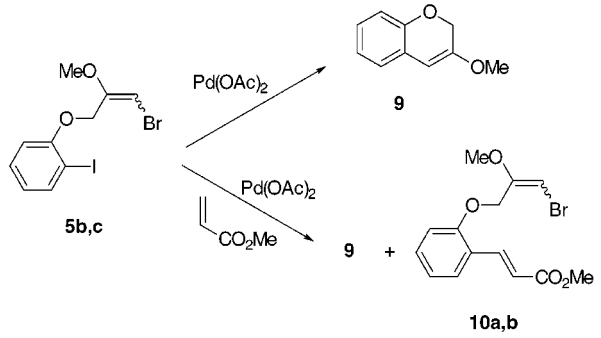


5 **6** **7** **8**

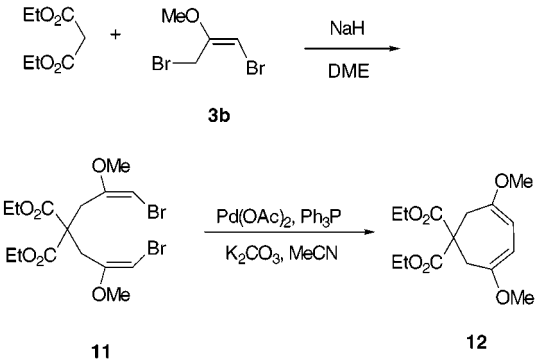
							yield (%)[a]		
entry	alkene	X	R	equiv. alkyn	product	*E*/*Z*	**6**	**7**	**8**
1	**5a**	H	TMS	1.1	**6a**	*Z*	45		
2	**5a**	H	Bu	1.1	**6b**	*Z*	67		
3	**5b**	I	Bu	1.1	**7a/8a**	*Z*	0	60	16
4	**5c**	I	Bu	1.1	**7b**	*E*	0	67	0
5	**5b**	I	TMS	4.0	**8b**	*Z*	0	0	72

[a] Isolated.

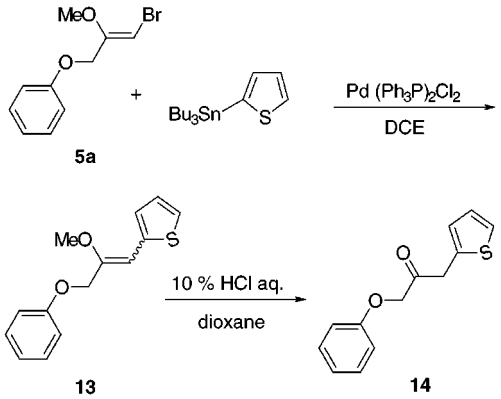
Scheme 1



Scheme 2



Scheme 3



cyclization, and **10a** or **10b** as the minor product (38% vs 16% and 40% vs 20%, respectively). Compounds **10a** and **10b** could, however, be prepared in good yields (92% and 72%, respectively) from methyl 3-(2-hydroxyphenyl)-acrylate[19] and **3a** or **3b**. Compounds **10a** and **10b** do not cyclize under the reaction conditions used in the Heck reaction.

Compound **9** was also obtained when **5b** or **5c** was reacted with hexabutylditin in the presence of palladium-(0) at 110 °C in toluene. In the former case the yield was 42%, and in the latter case it was 68%. Molecular models indicate that the cyclization of the *E*-isomer **5c** is much easier for steric reasons than the cyclization of the *Z*-isomer **5b**, hence the better yield in the case of **5c** compared to **5b**. Double bond isomerization in **5** most likely takes place at 110 °C, and an *E*-isomer is probably also the cyclizing species in the case of **5b**.

Alkylation of diethyl malonate with 2 equiv of **3b** gave the dialkylated malonate **11** in 82% yield (Scheme 2). Treatment of **11** with palladium gave the cyclized product **12** in 65% yield, as the only product. The methoxy groups probably block anything other than a 7-endo-trig cyclization. Also in this case is a β-bromide elimination preferred to a β-hydride elimination. The formation of a conjugated system may be of importance in this matter. The reaction is performed with an excess of triphenylphosphine, which presumably is also functioning as a reducing agent in addition to being a ligand.

The palladium-catalyzed reaction of organotin reagents with alkenyl halides (Stille reaction) is very versatile.[20] The first step in this reaction is believed to be oxidative addition of palladium(0) to the alkenyl halide. Little information on the rate of the oxidative additon of palladium(0) to an alkenyl halide having an electron-donating substituent in the β-position is available, but the methoxy group was expected to reduce the rate of the oxidative addition since a similar observation has been made in aromatic systems.[21] Compound **5a** did, however, react with 2-tributylstannylthiophene in DCE at 50 °C for 25 h to give the coupled product as a 1:1 mixture of *E*/*Z*-isomers in 73% yield. (Scheme 3).

Treatment of the enol ether **13** with acid gave the ketone **14**. (Scheme 3). The synthesis of **14** from 1,3-dibromo-2-methoxypropene is in essence the same as

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performing a nuceophilic substitution at C-1 and a palladium-catalyzed reaction on C-3 of 1,3-dibromo-2-propanone.

Conclusion

Diisopropylamine was the only base among a number of amines that showed high selectivity and gave a good chemical yield in the dehydrohalogenation of **2**. Photoisomerization of the Z-isomer of **3** gives access to the *E*-isomer. Nucleophilic displacement reactions of the allylic bromide in **3** occur mostly without any double bond isomerization, and the vinylic bromide of **3** could be utilized for palladium-catalyzed coupling reactions. The reactions performed indicate that 1,3-dibromo-2-methoxypropene might be a useful three-carbon unit for organic synthesis.

Experimental Section

General Methods. All air- and moisture-sensitive reactions were performed under an atmosphere of dry nitrogen. All solvents were dried over the standard drying agents and freshly distilled prior to use. For flash chromatography, 400−230 mesh silica gel 60 was employed. ^{1}H NMR spectra were recorded at 200, 300, or 500 MHz, and the ^{13}C NMR spectra were recorded at 75 MHz. Mass spectra, under electron impact conditions, were recorded at 70 eV ionizing energy. UV reactions were conducted in a quartz immersion well reactor using a low-pressure mercury lamp from Applied Photophysics (model 3020; 90% of the radiation at 254 nm). pK_{BH}: ethyldiisopropylamine,[22] DBU,[23] 2,6-lutidine,[24] DMAP,[25] diisopropylamine,[26] and *tert*-butylamine.[27]

1,2,3-Tribromo-2-methoxypropane (2). Acetyl bromide in dry dichloromethane (10 mL of 1 M, 10 mmol) was added to a solution of **1** (1.29 g, 4.9 mmol) in dry dichloromethane under N_2 at 0 °C. The mixture was stirred for 4 h at ambient temperature before the solvent was removed under reduced pressure. The crude product was sufficiently pure to be used in the next step but could be purified by Kugelrohr distillation (1.14 g, 75%). Oven temperature: 68−70 °C/0.1−0.2 mmHg. ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.54 (3H, s), 4.04 (2H, s). ^{13}C NMR (75 MHz, $CDCl_3$): δ 36.2, 54.9, 104.0.

***(Z)*-1,3-Dibromo-2-methoxypropene (3a).** Diisopropylamine (0.71 mL, 5.0 mmol) was added dropwise to a solution of **2** (1.52 g, 4.9 mmol) in dry dichloromethane (10 mL) at 0 °C under N_2. The mixture was stirred at ambient temperature for 4 h before a saturated solution of NH_4Cl was added, followed by diethyl ether. The aqueous phase was extracted with diethyl ether. The combinded organic phase was dried ($MgSO_4$) and evaporated. The crude product was purified by silica gel chromatography with hexane/ethyl acetate 7:1 as eluent to afford **3a** as a colorless oil (1.01 g, 90%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.85 (3H, s), 4.00 (2H, s), 5.62 (1H, s). ^{13}C NMR (75 MHz, $CDCl_3$): δ 27.7, 56.9, 89.1, 153.1. MS (EI): *m/z* 232/230/228 (16/31/16, M^+), 151 (97, $[M - Br]^+$), 149 (100, $[M - Br]^+$). HRMS (EI): calcd for $C_4H_6OBr_2$ 227.8790, found 227.8785.

***(E)*-1,3-Dibromo-2-methoxypropene (3b). Method 1.** Compound **2** (2.77 g, 8.9 mmol) in dry DMF (15 mL) was added to a mixture of K_2CO_3 (1.25 g, 9 mmol) in dry DMF (15 mL) at 0 °C under N_2. The mixture was stirred at ambient temperature for 4 h before a saturated solution of NH_4Cl was added, followed by diethyl ether. The aqueous phase was extracted with diethyl ether, and the combinded organic phase was washed with brine and water, dried ($MgSO_4$), and evaporated. The crude product was purified by silica gel chromatography with hexane/ethyl acetate 7:1 as eluent to afford **3b** as a colorless oil (0.92 g, 45%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.62 (3H, s), 4.10 (2H, s), 5.35 (1H, s). ^{13}C NMR (75 MHz, $CDCl_3$): δ 28.4, 56.4, 82.0, 156.4. MS (EI): *m/z* 232/230/228 (15/33/17, M^+), 151 (98, $[M - Br]^+$), 149 (100, $[M - Br]^+$). HRMS (EI): calcd for $C_4H_7OBr_3$ 227.8790, found 227.8787.

Method 2. Compound **3a** (120 mg, 0. 53 mmol) in dry hexane (10 mL) was irradiated with a low-pressure mercury lamp for 5 h under N_2 at ambient temperature. The solvent was evaporated off, and the crude product (120 mg) was analyzed by TLC, GLC, and ^{1}H NMR, which showed that a complete isomerzation to **3b** had taken place. Only minor impurities (<5%) were observed by ^{1}H NMR and GLC.

General Procedure for the Preparation of 5a−d. The alcohol (1.5 mmol) in dry DME (2 mL) was added to sodium hydride (1.6 mmol) in dry DME (2 mL) at 0 °C under N_2. After 15 min at 0 °C a solution of **3a** or **3b** in dry DME (2 mL) was added. The mixture was stirred at ambient temperature for 18 h before a mixture of NH_4Cl (aqueous) and diethyl ether was added. The aqueous phase was extracted with diethyl ether, and the combinded organic phase was washed with brine and water, dried ($MgSO_4$), and evaporated. The crude product was purified by silica gel chromatography.

3-Methoxy-2*H*-chromene (9). Method 1. Ethyldiisopropylamine (71 mg, 0.55 mmol) and compound **5b** (81 mg, 0.22 mmol) were added to a mixture of palladium acetate (10 mg, 0.045 mmol) and lithium chloride (10 mg, 0.24 mmol) in DMF (3 mL) under N_2 at ambient temperature. The mixture was stirred at 50 °C for 44 h, cooled, and diluted with diethyl ether. NH_4Cl (aqueous) was added, and the aqueous phase was extracted with diethyl ether. The combined organic phase was washed with brine and water and dried ($MgSO_4$). Evaporation gave the crude product, which was purified by silica gel chromatography using hexane/ethyl acetate 5:1 as eluent to afford **9** as a colorless oil (22 mg, 61%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.72 (3H, s), 4.58 (2H, s), 5.51 (1H, s), 6.76−6.93 (4H, m).^{13}C NMR (300 MHz, $CDCl_3$): δ 55.0, 65.9, 92.9, 115.2, 121.8, 123.4, 125.4, 126.1, 151.0, 152.8. MS(EI): *m/z* 162 (95, M^+), 161 (100, $[M - H]^+$), 147 (21, $[M - CH_3]^+$), 131 (52, $[M - OCH_3]^+$). HRMS (EI): calcd for $C_{10}H_{10}O_2$ 162.0680, found 162.0672.

Method 2. A mixture of compound **5c** (66 mg, 0.18 mmol) and hexabutylditin (133 mg, 0.23 mmol) in dry toluene (5 mL) was added to a solution of tetrakis(triphenylphosphine)-palladium (10 mg, 0.01 mmol) in dry toluene (4 mL) under N_2. The mixture was stirred at 110 °C for 24 h, cooled to room temperature, and diluted with toluene before a saturated solution of KF was added. The organic phase was filtered through a short pad of Celite, and the Celite was washed with pentane. The aqueous phase was extracted with pentane, and the combined organic phase was washed with brine and water and dried ($MgSO_4$). Evaporation gave the crude product, which was purified by silica gel chromatography using hexane/ethyl acetate 5:1 as eluent to afford **9** as a colorless oil (21 mg, 68%).

Diethyl 2,2-Bis[(*E*)-3-bromo-2-methoxyallyl]malonate (11). Diethyl malonate (46 mg, 0.29 mmol) in dry DME (1 mL) was added to sodium hydride (22 mg, 95% in paraffin, 0.87 mmol) in dry DME (3 mL) at 0 °C under N_2. The mixture was stirred at 0 °C for 15 min before a solution of **3b** in dry DME (1 mL) was added. The mixture was stirred at ambient temperature for 37 h before a mixture of aqueous NH_4Cl (aqueous) and diethyl ether was added. The aqueous phase was extracted with diethyl ether, and the combined organic phase was washed with brine and water, dried ($MgSO_4$), and evaporated. The crude product was purified by silica gel chromatography using hexane/ethyl acetate 7:1 as eluent to afford **11** as a colorless oil (110 mg, 85%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.20 (6H, t, J = 7.1 Hz), 3.08 (4H, s), 3.47 (6H, s), 4.12 (4H, q, J = 7.1 Hz), 5.19 (2 × 1H, s). ^{13}C NMR (75 MHz, $CDCl_3$): δ 13.9, 33.6, 55.1, 55.2, 61.4, 80.4, 155.9, 170.3. MS-

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(EI): *m*/*z* 460/458/456 (0.14/0.25/0.14, M^+), 385 (7, [M − $EtO_2C]^+$), 379 (12, [M − Br]$^+$), 377 (12, [M − Br]$^+$).

Diethyl (3*E*,5*E*)-3,6-Dimethoxycyclohepta-3,5-diene-1,1-dicarboxylate (12). Compound **11** (55 mg, 0.12 mmol) in dry acetonitrile (2 mL) was added to a mixture of palladium acetate (5 mg, 0.024 mmol), triphenylphosphine (44 mg, 0.17 mmol), and K_2CO_3 (48 mg, 0.35 mmol) in dry acetonitrile (10 mL) under N_2 at ambient temperature. The mixture was heated under reflux for 24 h, cooled, and a mixture of NH_4Cl (aqueous) and diethyl ether was added. The aqueous phase was extracted with diethyl ether, and the combined organic phase was washed with brine and water, dried ($MgSO_4$), and evaporated. The crude product was purified by silica gel chromatography using hexane/ethyl acetate 3:1 as eluent to afford **12** as a colorless oil (22 mg, 65%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.20 (6 H, t, J = 7.1 Hz), 2.80 (4H, s), 3.49 (6H, s), 4.15 (4H, q, J = 7.1 Hz), 4.87 (2 × 1H, s). ^{13}C NMR (75 MHz, $CDCl_3$): δ 13.9, 37.7, 54.7, 60.4, 61.5, 94.1, 155.1, 170.6. MS-(EI): *m*/*z* 298 (35, M^+), 253 (5, [M − EtO]$^+$), 195 (26, [M − $EtO_2C/2 \times CH_3]^+$). HRMS (EI): calcd for $C_{15}H_{22}O_6$ 298.1416, found 298.1402.

2-Methoxy-3-(2-thienyl)allyloxybenzene (13). A mixture of compound **5b** (241 mg, 1.0 mmol) and 2-thienyltributyltin (0.76 g, 2.0 mmol) in dry degassed DCE (4 mL) was added to a solution of bis(triphenylphosphine)palladium dichloride (40 mg, 0.05 mmol) in dry degassed DCE (2 mL) under N_2 at ambient temperature. The mixture was stirred at 50 °C for 25 h, diluted with DCE, and added to a saturated aqueous solution of KF. The organic phase was filtered through a short pad of Celite, and the Celite was washed with pentane. The aqueous phase was extracted with pentane, and the combined organic phase was washed with brine and water and dried ($MgSO_4$). Evaporation gave the crude product, which was purified by silica gel chromatography using hexane/chloroform 2:1 as eluent to afford **13** as a colorless oil (0.18 g, 73%, as 1:1 mixture of the *E*/*Z* isomers). ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.86 (3H, s), 3.89 (3H, s), 4.54 (2H, s), 4.67 (2H, s), 5.61 (1H, s), 6.11 (1H, s), 6.90−7.01 (10H, m), 7.27−7.31 (6H, m). ^{13}C NMR (75 MHz, $CDCl_3$): δ 56.1, 57.1, 66.1, 66.8, 88.2, 106.7, 114.8, 114.9, 121.4, 121.7, 125.2, 125.8, 126.1, 129.5, 129.6, 137.7, 148.6, 153.0, 157.7, 158.1. MS (EI): *m*/*z* 246 (11, M^+), 153 (100, [M − PhO]$^+$). HRMS (EI): calcd for $C_{14}H_{14}O_2S$ 246.0715, found 246.0716.

1-Phenoxy-3-(2-thienyl)propanone (14). Compound **13** (17 mg, 0.069 mmol) was dissolved in dioxane (1.2 mL), and 10% HCl (0.25 mL) was added. The mixture was stirred at ambient temperature for 13 h before diethyl ether and a saturated solution of Na_2CO_3 (aqueous) were added. The aqueous phase was extracted with diethyl ether, and the combined organic phase was washed with water and dried ($MgSO_4$). The crude product was purified by silica gel chromatography using hexane/ethyl acetate 15:1 as eluent to afford **14** as a colorless oil (6 mg, 40%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.11 (2H, s), 4.62 (2H, s), 6.86−6.99 (5H, m), 7.21−7.32 (3H, m). ^{13}C NMR (75 MHz, $CDCl_3$): δ 40.0, 72.0, 87.7, 114.5, 121.9, 125.4, 127.1, 127.2, 129.7, 157.6, 203.6. MS (EI): *m*/*z* 232 (45, M^+), 139 (46, [M − PhO]$^+$). HRMS (EI): calcd for $C_{13}H_{12}O_2S$ 232.0558, found 232.0553.

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Supporting Information Available: Experimental data for **5a**−**f**, **6a** and **6b**, **7a** and **7b**, **8a** and **8b**, and **10a** and **10b**; copy of ^{1}H NMR spectrum of **5e**; copies of ^{1}H and ^{13}C NMR spectra of **2**, **3a,b**, **5a**−**d**, **6a,b**, **7a,b**, **8a,b**, **9**, **10a,b**, and **11**−**14**. This material is available free of charge via the Internet at http://pubs.acs.org.

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