Generation and Cyclization of Acyl Radicals from Thiol Esters Under Nonreducing, Tin-Free Conditions

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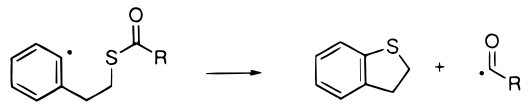
The preparation of 2-(2-((*tert*-butyloxycarbonyl)amino)phenyl)ethyl mercaptan from 2-(2-aminophenyl)ethanol is described. This thiol is condensed with a series of suitably unsaturated carboxylic acids to give a series of thiol esters. The Boc group is removed and the amine reacted with isoamyl nitrite to give a series of diazonium salts. Exposure to iodide in acetone solution then generates the aryl radical, which undergoes intramolecular homolytic substitution at sulfur with liberation of the acyl radical. Following acyl radical cyclization, quenching by iodine and then elimination of HI leads to the isolation of α-methylene cycloalkanones in good yield.

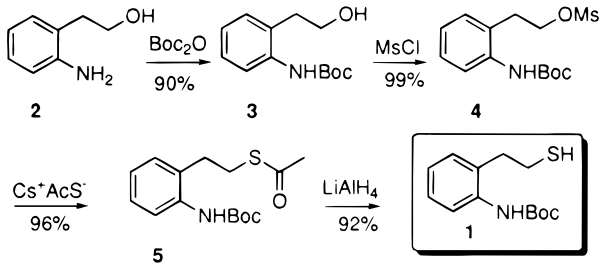
Thiol esters are very poor sources of acyl radicals, both photochemically and in conjunction with standard silanes and stannanes.[1] This lack of reactivity may be overcome, as we have recently demonstrated,[2] by the inclusion of a simple additional propagation step in which an aryl radical brings about an intramolecular homolytic substitution[3] at sulfur (Scheme 1).[4] In developing this chemistry, we generated the requisite aryl radical from the corresponding aryl iodide with tributyltin hydride, allyltributylstannane, or tris(trimethylsilyl)silane.[2] We next set ourselves the goal of avoiding the use of such reducing conditions and, in the case of the tin-based reagents, the attendant problems of purification and disposal. The answer, we surmised, lay in the use of arenediazonium ions as convenient precursors to aryl radicals.

Beckwith has elegantly demonstrated that arenediazonium salts function as efficient sources of aryl radicals when exposed to suitable electron donors, such as iodide and thiolate anions, and that such chemistry may be employed in radical cyclization onto alkenes.[5−7] In recent years, Murphy has astutely exploited this means of aryl radical generation, coupled with the use of tetrathiafulvene as electron donor and, via its radical cation, eventual radical trap in synthesis.[8−13] In all of this chemistry, as in the classical, mechanistically related Meerwein arylation,[14] the arene ring of the aryl radical

Scheme 1



Scheme 2



necessarily becomes an intimate part of the target molecule. In the concept set out here, the aryl radical merely serves as a convenient handle, thus removing the need to design any synthesis around this nucleus.

We began our study with the synthesis of the crystalline thiol **1** (Scheme 2). Reaction of amino alcohol **2** with Boc_2O gave carbamate **3**, which was transformed into mesylate **4** and then to thiol acetate **5** by displacement with cesium thioacetate.[15] Selective reduction of the thiol ester function provided **1**. The overall yield for this straightforward, four-step protocol was 79%.

Thiol **1** was then condensed with a number of acids, via the acid chlorides, to give the thiol esters (**11**−**17**, Chart 1) in 77−85% yield (Table 1). The previously unknown 2-allyl-4-nitrobenzoic acid (**8**) was readily obtained by Stille coupling[16] of commerical methyl 2-bromo-4-nitrobenzoate (**6**) with allyltributyltin as illustrated in Scheme 3. Alkylation of diethyl allylmalonate with *tert*-butyl bromoacetate followed by exposure to trifluoroacetic acid provided the only other new substrate (**10**) (Scheme 4).

Each ester was exposed to hydrogen chloride in ethyl acetate leading to removal of the Boc protecting groups

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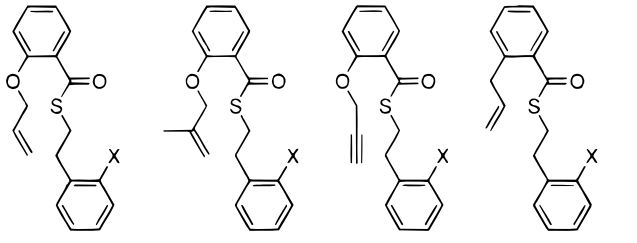
Table 1. Cyclization of Diazonium Salts

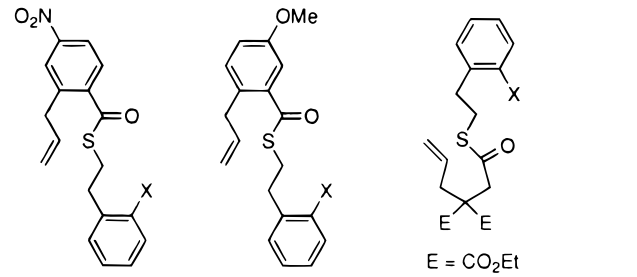
entry	esterification product (% yield)	deprotection product (% yield)	diazotization product (% yield)	cyclization reagent	cyclization product (% yield)
1	**11** (82)	**18** (95)	**25** (90)	NaI	**32** (81)
2	**12** (80)	**19** (95)	**26** (91)	NaI	**34** (85)
3	**13** (85)	**20** (95)	**27** (90)	NaI	**35** (50)[a] + **32** (25)
4	**14** (80)	**21** (94)	**28** (86)	NaI	**36** (75) + **37** (10)
5	**15** (80)	**22** (96)	**29** (88)	NaI	**38** (trace) + **39** (24) + **40** (37)
6	**16** (77)	**23** (96)	**30** (90)	NaI	**41** (88)
7	**17** (81)	**24** (93)	**31** (90)	NaI	**42** (70)
8	**11**[b]	**18**[b]	**25**[b]	CuCN	**54** (36) + **32** (12) + **55** (12)
9	**12**[c]	**19**[c]	**26**[c]	NaSPh	**56** (35)

[a] A single isomer, tentatively assigned the *E*-configuration owing to the absence of an NOE correlation between the methylene and olefinic hydrogens. [b] As entry 1. [c] As entry 2.

Chart 1

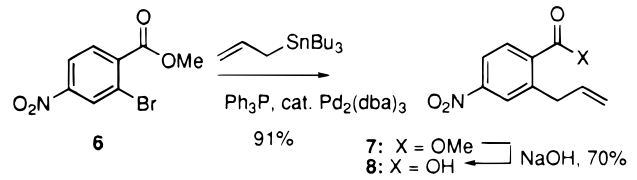


11: X = NHBoc **12:** X = NHBoc **13:** X = NHBoc **14:** X = NHBoc
18: X = NH_3Cl **19:** X = NH_3Cl **20:** X = NH_3Cl **21:** X = NH_3Cl
25: X = $N_2^+BF_4^-$ **26:** X = $N_2^+BF_4^-$ **27:** X = $N_2^+BF_4^-$ **28:** X = $N_2^+BF_4^-$



15: X = NHBoc **16:** X = NHBoc **17:** X = NHBoc
22: X = NH_3Cl **23:** X = NH_3Cl **24:** X = NH_3Cl
29: X = $N_2^+BF_4^-$ **30:** X = $N_2^+BF_4^-$ **31:** X = $N_2^+BF_4^-$

Scheme 3

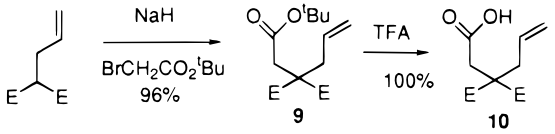


6 91% **7:** X = OMe **8:** X = OH

and isolation of the amines as their hydrochloride salts (**18**−**24**) in close to quantitative yield (Table 1). Finally, ethanolic solutions of these amine hydrochloride salts were exposed to tetrafluoroboric acid and isoamyl nitrite, permitting isolation of the desired diazonium ions as their tetrafluoroborate salts (**25**−**31**) in excellent yield (Table 1).

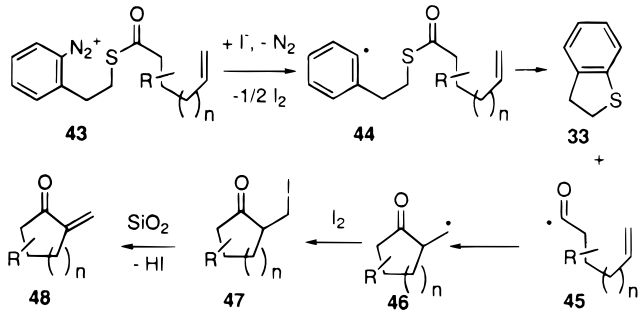
Dropwise addition of a solution of sodium iodide in acetone to diazonium salt **25** stirred in thoroughly degassed acetone at room temperature resulted, after 6 h, in the isolation of the methylenechromanone **32** and the dihydrobenzothiophene **33** (Chart 2) in 81 and 90% yields, respectively (Table 1, entry 1). These observations are best rationalized in terms of the general mechanism of Scheme 5. Electron transfer from I^- to the diazonium salt (**43**) results in an aryl radical (**44**) which participates in an intramolecular S_H2 reaction at sulfur so liberating

Scheme 4



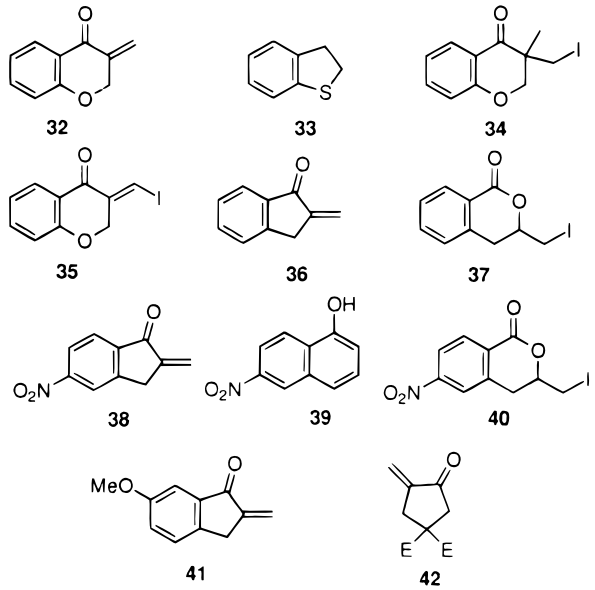
9 **10**

Scheme 5



43 **44** **33** **48** **47** **46** **45**

Chart 2



32 **33** **34** **35** **36** **37** **38** **39** **40** **41** **42**

the acyl radical (**45**). Cyclization in the exo mode[17] gives the primary radical (**46**) which is trapped by iodine, giving the primary product (**47**). Elimination of HI from this β-iodo ketone provides the observed α-methylenecycloalkanone (**48**). The ^1H NMR spectrum of the crude reaction mixture is consistent with the formation of the α-(iodomethyl)cycloalkanone (**47**) as the primary reaction product, with elimination occurring on attempted chromatography over silica gel.

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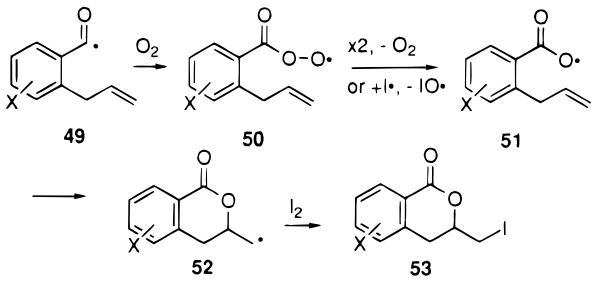
Further examples illustrating the effectiveness of this chemistry with the 5- and 6-exo mode cyclizations of aryl- and alkyl-derived acyl radicals are presented in Table 1. In each case **33** is formed as byproduct, as evident from the NMR spectra of the crude reaction mixtures. The overall transformation, with the formation of exomethylene cycloalkanones, is somewhat analogous to that obtained earlier with acyl tellurides.[17] However, the new chemistry is also applicable to aliphatic carboxylic acids (Table 1, entry 7) whereas the earlier method was only suited to aryl and α,β-unsaturated acid derivatives. Moreover, the stoichiometric use of organotellurium derivatives of unknown toxicity is avoided.

With diazonium salt **28** an unanticipated byproduct plagued our early experiments. This compound was isolated and identified as the known iodo lactone **37**. Our first reaction, naturally, was that this product arose from a competing, polar iodolactonization of either the thiol ester itself or of the acid formed by *in situ* hydrolysis of the thiol ester by adventitious water. However, control experiments, in which 2-allylbenzoic acid and the *N*-*t*-Boc-protected thiol ester (**14**) were exposed to the reaction conditions, soon revealed that this was not the case. A further experiment, in which 2-allylbenzoic acid was irradiated in acetone in the presence of iodine and iodobenzene diacetate,[18] however, did lead to the rapid formation of the iodo lactone **37** and its isolation in 95% yield. It seems likely, therefore, that **37** is the product of cyclization of a carboxyl radical onto the alkene followed by trapping by iodine. The cyclization of aryloxyl radicals, whose decarboxylation is slow,[19,20] onto suitably disposed alkenes and arenes is a known process.[21,22] This in turn posed the question "what is the origin of the carboxyl oxygen ?" We reasoned that it might reasonably come from adventitious water and hydrolysis of the thiol ester to the acid, or from imperfectly excluded oxygen. Of these, the latter possibility seemed the more likely. Indeed, when the reaction was repeated after rigorously degassing of the solvent by a series of freeze−thaw cycles the yield of iodo lactone **37** was reduced to 10% and that of the desired, cyclized product rose to the 75% reported in Table 1.[23] All subsequent reactions therefore included a rigorous sequence of freeze−thaw cycles. The identification of molecular oxygen as the culprit demands a mechanism for the formation of acyloxy radicals from acyl radicals and oxygen. We presume (Scheme 6) that the acyl radical (**49**) is quenched by oxygen, giving an acylperoxyl radical (**50**). It would seem reasonable that two of these species combine to give a diacyl tetraoxide which then looses oxygen to give two carboxyl radicals (**51**) and so the observed cyclization. Such processes have been discussed in the context of gas and liquid phase autoxidations of aldehydes.[22,24,25] Alternatively, and perhaps

Scheme 6



preferable in view of the dilution and the consequent improbability of bimolecular radical−radical reactions, reaction with iodine occurs to give a periodite which then furnishes the acyloxyl radical (**51**). A final point of note here is the preference of the acyloxyl radical (**51**) for cyclization in the 6-exo-trig mode over and above 1,5-hydrogen atom abstraction from a benzylic-allylic site.[22]

A noteworthy exception to the smooth 5-exo-trig cyclizations reported was provided by the *p*-nitro-substituted system **29** (Table 1, entry 5). With this substrate we were unable to isolate significant quantities of the anticipated 2-methyleneindanone **38**, but obtained instead the naphthol **39** and the iodo lactone **40**, and this latter despite all our attempts to exclude oxygen from the system. This change in behavior is clearly a function of the *p*-nitro group as the congenors **28** and **30** (Table 1, entries 4 and 6) were perfectly well behaved. We are led to conclude that the *p*-nitro group reduces the nucleophilicity of the acyl radical significantly by (i) its strongly electron withdrawing nature and/or (ii) its ability to stabilize the acyl radical through resonance forms delocalizing the single electron. Of the two explanations, the former is perhaps more likely as benzoyl radicals, being σ-type radicals with the single electron in the plane of the aromatic ring, are relatively insensitive to resonance effects.[26] This reduced reactivity will retard the cyclization and so increase the likelihood of trapping by extraneous oxygen and, hence, iodo lactone formation. The naphthol **39** is the product of a formal 6-endo mode cyclization. This may arise through the additional stabilization provided by the *p*-nitro group, rendering the normally irreversible[27] 5-exo-trig acyl radical cyclization reversible. Alternatively, it is possible that the *p*-nitro group promotes a rapid expansion of a kinetic 5-exo-cyclized radical, via a cyclopropyloxy radical, as studied by Beckwith, Dowd, and others.[28] Indeed, electron-withdrawing substituents substantially accelerate the mechanistically related neophyl rearrangement.[29]

As Beckwith and Murphy have demonstrated, the generation of aryl radicals from diazonium salts is by no means limited to the use of iodide as an electron source. We have not conducted an extensive survey at the present time but have demonstrated that both cyanide and thiophenate anions may be used to replace iodide (Table 1, entries 8 and 9, respectively). Although the yield is at present only moderate, the use of cuprous cyanide for this purpose is especially interesting in so

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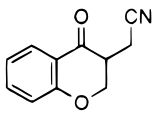
far as it permits the formation of an additional C−C bond. The byproducts **32** and **55**, from the reaction of **25** with CuCN, are readily understood in terms of oxidation of the initial cyclized radical, perhaps by electron transfer to a further molecule of substrate (**25**), and by quenching by hydrogen atom abstraction from the solvent, DMSO, respectively.



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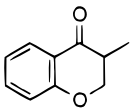

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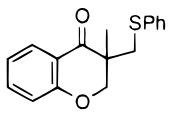

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Experimental Section

General. Unless otherwise stated ^{1}H and ^{13}C NMR spectra were recorded as $CDCl_3$ solutions at 300 and 75 MHz, respectively, with chemical shifts (δ) in ppm downfield from tetramethylsilane as internal standard. All solvents were dried and distilled by standard methods. Acetone was distilled under Ar from 4 Å molecular sieves and then subjected to three freeze−thaw cycles for use in the radical reactions. Extracts were dried over Na_2SO_4, and solvents were removed *in vacuo*. Microanalyses were performed by Midwest Microlabs, Indianapolis, IN.

2-(2-((*tert*-Butyloxycarbonyl)amino)phenyl)ethanol (3). To a stirred 0 °C solution of 2-(2-aminophenyl)ethanol (**2**) (1.37 g, 10 mmol) in a mixture of dioxane (10 mL), water (5 mL), and saturated $NaHCO_3$ (5 mL) was added di-*tert*-butyl dicarbonate (2.40 g, 11 mmol). The reaction mixture was stirred at room temperature for 4 h before water (20 mL) was added. The organic layer was separated and the aqueous phase extracted with EtOAc (2 × 10 mL). The combined extracts were washed with water and brine and then were dried. Removal of the solvent gave the crude product as a white solid which was recrystallized from CH_2Cl_2/hexane to give **3** as colorless crystals (2.13 g, 90%): mp 128−129 °C; ^{1}H NMR δ 1.51 (s, 9H), 2.09 (s, 1H), 2.83 (t, J = 5.7 Hz, 2H), 3.89 (t, J = 5.8 Hz, 2H), 7.05 (td, J = 7.4, 1.1 Hz, 1H), 7.14 (dd, J = 7.6, 1.1 Hz, 1H), 7.22 (td, J = 7.4, 1.7 Hz, 1H), 7.65 (s, 1H), 7.71 (d, J = 8.1 Hz, 1H); ^{13}C NMR δ 28.3, 34.5, 64.1, 80.0, 122.9, 124.1, 127.2, 130.1, 130.7, 137.0, 153.7. Anal. Calcd for $C_{13}H_{19}NO_3$: C, 65.80, H, 8.07. Found: C, 66.16, H, 8.14.

2-(Mesyloxy)-1-(2-((*tert*-butyloxycarbonyl)amino)phenyl)ethane (4). To a stirred mixture of **3** (0.711 g, 3 mmol) and Et_3N (1.2 mL, 8.6 mmol) in THF (12 mL) cooled to −30 °C was added dropwise a solution of mesyl chloride (0.46 mL, 6 mmol) in THF (6 mL) over 20 min. After a further 20 min stirring, aqueous NH_4Cl was added to render the solution acidic. The organic layer was separated and the aqueous layer extracted with EtOAc (3 × 10 mL). The combined extracts were washed with water and brine and then dried, and concentrated to dryness. The residue was crystallized from CH_2Cl_2, giving **4** as white needles (0.93 g, 99%): mp 104 °C; ^{1}H NMR δ 1.51 (s, 9H), 2.83 (s, 3H), 3.04 (t, J = 6.6 Hz, 2H), 4.42 (t, J = 6.6 Hz, 2H), 6.51 (s, 1H), 7.13 (t, J = 7.4 Hz, 1H), 7.18−7.26 (m, 2H), 7.62 (d, J = 7.9Hz, 1H); ^{13}C NMR δ 28.2, 31.3, 37.1, 69.6, 80.6, 124.2, 125.1, 128.0, 128.5, 130.2, 136.1, 153.6. Anal. Calcd for $C_{14}H_{21}NO_5S$: C, 53.32, H, 6.71. Found: C, 53.26, H, 6.70.

(*S*)-2-(2-((*tert*-Butyloxycarbonyl)amino)phenyl)ethyl Thioacetate (5). To a stirred solution of cesium thioacetate (4.66 g, 14.3 mmol) in DMF (70 mL) at room temperature was added **4** (4.10 g, 13 mmol) in DMF (30 mL). The reaction mixture was stirred for 14 h at room temperature before water (200 mL) was added. The mixture was extracted with EtOAc (3 × 100 mL), and the combined extracts were washed with water and brine and dried. Removal of the solvent followed by column chromatography on silica gel (eluent: CH_2Cl_2/hexane, 4:3) gave **5** as white crystals (3.69 g, 96%): mp 55−56 °C; ^{1}H NMR δ 1.55 (s, 9H), 2.39 (s, 3H), 2.76−2.82 (m, 2H), 2.91−2.96 (m, 2H), 7.00 (t, J = 7.3 Hz, 1H), 7.12 (d, J = 6.6 Hz, 1H), 7.23 (t, J = 8.7 Hz, 1H), 7.40 (s, 1H), 7.91 (d, J = 8.0 Hz, 1H); ^{13}C NMR δ 28.3, 29.2, 30.7, 32.3, 80.2, 121.6, 123.5, 127.6, 128.9, 129.6, 136.5, 153.5, 196.9. Anal. Calcd for $C_{15}H_{21}NO_3S$: C, 60.99, H, 7.17. Found: C, 61.08, H, 7.20.

2-(2-((*tert*-Butyloxycarbonyl)amino)phenyl)ethanethiol (1). A solution of **5** (2.94 g, 10 mmol) in Et_2O (100 mL) cooled to −20 °C was treated with $LiAlH_4$ (0.57 g, 15 mmol). The reaction mixture was stirred at 0 °C for 1.5 h before it was quenched with dilute aqueous HCl (3 M, 20 mL). The organic layer was separated, washed with water, $NaHCO_3$, and brine, and dried. Removal of the solvent followed by column chromatography on silica gel (eluent: CH_2Cl_2/hexane, 1:2) gave **1** (2.33 g, 92%) as a white solid: mp 44−45 °C; ^{1}H NMR δ 1.46 (t, J = 8.1 Hz, 1H), 1.52 (s, 9H), 2.77−2.83 (m, 2H), 2.91 (t, J = 6.9 Hz, 2H), 6.56 (s, 1H), 7.08 (t, J = 7.1 Hz, 1H), 7.15 (dd, J = 7.6, 1.1 Hz, 1H), 7.23 (t, J = 7.4 Hz, 1H), 7.69 (d, J = 8.3 Hz, 1H); ^{13}C NMR δ 25.0, 28.3, 35.4, 80.4, 123.5, 124.6, 127.3, 129.7, 130.9, 135.9, 153.4. Anal. Calcd for $C_{13}H_{19}NO_2S$: C, 61.63, H, 7.56. Found: C, 61.62, H, 7.47.

Procedure A: Preparation of Thiol Esters. A solution of the appropriate carboxylic acid (1 mmol) in benzene (10 mL) was treated at room temperature with oxalyl chloride (0.87 mL, 10 mmol) and a small drop of DMF. After 0.5 h, the solvent and excess reagent were removed and CH_2Cl_2 (15 mL) was added. DMAP (159 mg, 1.3 mmol) was then added followed by thiol **1** (278 mg, 1.1 mmol). The resulting mixture was stirred at room temperature until the reaction was complete (TLC control). EtOAc (60 mL) was then added and the resulting solution washed with water, $NaHCO_3$, and brine and dried. Removal of solvent followed by column chromatography on silica gel gave the pure thiol ester.

(*S*)-2-(2-((*tert*-Butyloxycarbonyl)amino)phenyl)ethyl 2-(allyloxy)thiobenzoate (11) was prepared from 2-(allyloxy)benzoic acid[17] according to procedure A: chromatography eluent, CH_2Cl_2/hexane, 1/1; white solid; mp 61−62 °C; ^{1}H NMR δ 1.57 (s, 9H), 2.85−2.91 (m, 2H), 3.03−3.09 (m, 2H), 4.71 (dt, J = 5.2, 1.5 Hz, 2H), 5.34 (dd, J = 10.5, 1.4 Hz, 1H), 5.51 (dd, J = 17.3, 1.5 Hz, 1H), 6.09−6.15 (m, 1H), 7.01−7.06 (m, 3H), 7.17 (dd, J = 7.6, 1.6 Hz, 1H), 7.25 (t, J = 3.8 Hz, 1H), 7.48 (td, J = 6.6, 0.7 Hz, 1H),7.91−7.94 (m, 2H), 8.00 (d, J = 8.1 Hz, 1H); ^{13}C NMR δ 28.3, 29.6, 32.6, 69.8, 79.9, 113.3, 118.2, 120.7, 121.2, 123.2, 126.4, 127.5, 129.0, 129.7, 129.9, 132.4, 134.0, 136.6, 153.7, 157.7, 191.5. Anal. Calcd for $C_{23}H_{27}NO_4S$: C, 66.80, H, 6.58. Found: C, 67.03, H, 6.80.

(*S*)-2-(2-((*tert*-Butyloxycarbonyl)amino)phenyl)ethyl 2-(methallyloxy)thiobenzoate (12) was prepared from 2-(methallyloxy)benzoic acid[17] according to procedure A: chromatography eluent, CH_2Cl_2/hexane, 2:1; colorless oil; ^{1}H NMR δ 1.57 (s, 9H), 1.91 (d, J = 0.4 Hz, 3H), 2.86−2.91 (m, 2H), 3.04−3.09 (m, 2H), 4.59 (s, 2H), 5.05 (t, J = 1.4 Hz, 1H), 5.19 (q, J = 0.9 Hz, 1H), 6.98−7.05 (m, 3H), 7.17 (dd, J = 7.6, 1.6 Hz, 1H), 7.25 (t, J = 7.4 Hz, 1H), 7.47 (td, J = 8.4, 1.8 Hz, 1H), 7.90−7.93 (m, 2H), 8.03 (d, J = 7.4 Hz, 1H); ^{13}C NMR δ 19.6, 28.3, 29.6, 32.5, 72.6, 79.9, 113.1, 113.7, 120.5, 121.2, 123.2, 126.3, 127.5, 129.0, 129.7, 129.8, 133.9, 136.6, 140.0, 153.7, 157.7, 191.6. Anal. Calcd for $C_{24}H_{29}NO_4S$: C, 67.42, H, 6.84. Found: C, 67.61, H, 7.03.

(*S*)-2-(2-((*tert*-Butyloxycarbonyl)amino)phenyl)ethyl 2-(propargyloxy)thiobenzoate (13) was prepared from 2-(propargyloxy)benzoic acid[17] according to procedure A: chromatography eluent, CH_2Cl_2; colorless oil (350 mg, 85%); ^{1}H NMR δ 1.57 (s, 9H), 2.57 (t, J = 2.3 Hz, 1H), 2.86−2.91 (m, 2H), 3.04−3.10 (m, 2H), 4.85 (d, J = 2.3 Hz, 2H), 7.01 (t, J = 7.1 Hz, 1H), 7.09 (t, J = 7.6 Hz, 1H), 7.17 (d, J = 5.6 Hz, 2H), 7.25 (t, J = 7.6 Hz, 1H), 7.52 (td, J = 8.0, 1.6 Hz, 1H), 7.87 (s, 1H), 7.92 (dd, J = 7.8, 1.6 Hz, 1H), 7.99 (d, J = 8.2 Hz, 1 H); ^{13}C NMR δ 28.3, 29.7, 32.5, 56.5, 76.4, 77.4, 80.0, 113.6, 121.2, 121.5, 123.3, 126.3, 127.5, 128.9, 129.7, 130.0, 133.8, 153.6, 157.7, 191.6. Anal. Calcd for $C_{23}H_{25}NO_4S$: C, 67.13, H, 6,12. Found: C, 67.24, H, 5.99.

(*S*)-2-(2-((*tert*-Butyloxycarbonyl)amino)phenyl)ethyl 2-allylthiobenzoate (14) was prepared from 2-allylbenzoic acid[17] according to procedure A: chromatography eluent, CH_2Cl_2/hexane, 2:1; colorless oil; ^{1}H NMR δ 1.57 (s, 9H), 2.87−2.92 (m, 2H) 3.05−3.11 (m, 2H), 3.72 (d, J = 6.5 Hz, 2H), 5.04

(dd, J = 2.8, 1.8 Hz, 1H), 5.09 (dd, J = 3.0, 1.6 Hz, 1H), 5.92−6.03 (m, 1H), 7.04 (td, J = 7.4, 1.2 Hz, 1H), 7.19 (dd, J = 7.6, 1.5 Hz, 1H), 7.27−7.34 (m, 3H), 7.47 (td, J = 7.4, 1.3 Hz, 1H), 7.71 (s, 1H), 7.81 (dd, J = 8.3,1.0 Hz, 1H), 8.04 (d, J = 1.2 Hz, 1H); ^{13}C NMR δ 28.4, 29.7, 32.5, 37.5, 80.2, 116.2, 121.6, 123.5, 126.3, 127.7, 128.7, 129.8, 130.8, 132.1, 136.6, 137.1, 138.7, 153.6, 195.4. Anal. Calcd for $C_{23}H_{27}NO_3S$: C, 69.49, H, 6.85. Found: C, 69.22, H, 6.81.

(*S*)-2-(2-((*tert*-Butyloxycarbonyl)amino)phenyl)ethyl 2-allyl-4-nitrothiobenzoate (15) was prepared from **8** according to procedure A: chromatography eluent, CH_2Cl_2; yellow crystals; mp 64−65 °C; ^{1}H NMR δ 1.54 (s, 9H), 2.89−2.94 (m, 2H), 3.13−3.19 (m, 2H), 3.70 (d, J = 6.6 Hz, 2H), 5.08−5.18 (m, 2H), 5.86−5.96 (m, 1H), 7.04 (td, J = 7.4, 1.2 Hz, 1H), 7.18 (dd, J = 7.6, 1.6 Hz, 1H), 7.26 (td, J = 5.9, 1.6 Hz, 1H), 7.39 (s, 1H), 7.86 (d, J = 8.4 Hz, 1H), 7.92 (d, J = 8.0 Hz, 1H), 8.12−8.15 (m, 2H); ^{13}C NMR δ 28.6, 30.2, 32.4, 37.3, 80.5, 118.1, 121.6, 122.3, 124.0, 125.7, 129.0, 130.0, 135.0, 136.7, 140.8, 142.8, 149.5, 153.8, 194.7. Anal. Calcd for $C_{23}H_{26}N_2O_5S$: C, 62.43, H, 5.92. Found: C, 62.24, H, 5.82.

(*S*)-2-(2-((*tert*-Butyloxycarbonyl)amino)phenyl)ethyl 2-allyl-5-methoxythiobenzoate (16) was prepared from 2-allyl-5-methoxybenzoic acid according to the procedure A: chromatography eluent, CH_2Cl_2/hexane, 5:1; colorless crystals; mp 50−52 °C; ^{1}H NMR δ 1.55 (s, 9H), 2.85−2.90 (m, 2H), 3.04−3.10 (m, 2H), 3.60 (d, J = 6.5 Hz, 2H), 3.84 (s, 3H), 4.99 (dd, J = 6.2, 1.8 Hz, 1H), 5.04 (s, 1H), 5.84−5.96 (m, 1H), 6.97−7.05 (m, 2H), 7,16−7.31 (m, 4H), 7.61 (s, 1H), 7.98 (d, J = 8.2 Hz, 1H); ^{13}C NMR δ 2.84, 29.7, 32.5, 36.7, 55.4, 80.1, 114.1, 115.8, 117.5, 121.7, 123.6, 127.7, 129.0, 129.8, 130.4, 132.0, 136.7, 137.1, 138.0, 153.7, 157.8, 195.2. Anal. Calcd for $C_{24}H_{29}NO_4S$: C, 67.42, H, 6.84. Found: C, 67.34, H, 6.78.

(*S*)-2-(2-((*tert*-Butyloxycarbonyl)amino)phenyl)ethyl 3,3-bis(ethoxycarbonyl)-5-hexenethioate (17) was prepared from **10** according to procedure A: chromatography eluent, CH_2Cl_2; colorless oil; ^{1}H NMR δ 1.25 (t, J = 7.1 Hz, 6H), 1.54 (s, 9H), 2.74−2.82 (m, 4H), 2.93−2.98 (m, 2H), 3.26 (s, 2H), 4.20 (q, J = 7.1 Hz, 4H), 5.11 (s, 1H), 5.15 (s, 1H), 5.60−5.76 (m, 1H), 7.01 (t, J = 7.4 Hz, 1H), 7.07 (s, 1H), 7.12 (d, J = 6.9 Hz, 1H), 7.23 (t, J = 7.5 Hz, 1H), 7.85 (d, J = 8.1 Hz, 1H); ^{13}C NMR δ 13.9, 28.3, 28.9, 32.1, 37.1, 45.5, 52.1, 55.7, 61.7, 80.3, 120.0, 122.1, 123.8, 127.6, 128.9, 129.6, 132.0, 136.2, 153.6, 169.5, 196.9. Anal. Calcd for $C_{25}H_{35}NO_7S$: C, 60.83, H, 7.15. Found: C, 60.58, H, 6.99.

Procedure B: Removal of the Boc Group. The appropriate Boc-protected amines (1 mmol) were treated at room temperature with a 3 M HCl/EtOAc solution (5 mL). After the reaction was complete the solvent was removed and the residue was added into dry ether. The ether was then decanted and the residue further washed with ether several times. The resulting solid can be used directly for the next step.

(*S*)-2-(2-Aminophenyl)ethyl 2-(allyloxy)thiobenzoate HCl salt (18) was prepared from **11** according to procedure B: white solid; mp 131−132 °C; ^{1}H NMR (CD_3OD) δ 2.99−3.23 (m, 2H), 3.20−3.26 (m, 2H), 4.68 (dt, J = 5.1, 1.6 Hz, 2H), 5.26 (dt, J = 9.1, 1.6 Hz, 1H), 5.46 (dt, J = 17.3, 1.7 Hz, 1H), 6.05−6.14 (m, 1H), 7.04 (td, J = 7.3, 1.0 Hz, 1H), 7.12 (d, J = 8.4 Hz, 1H), 7.34−7.40 (m, 3H), 7.47−7.51 (m, 2H), 7.74 (dd, J = 7.8, 1.8 Hz, 1H); ^{13}C NMR (CD_3OD) δ 29.8, 31.7, 70.6, 114.7, 117.9, 121.5, 124.3, 127.3, 129.3, 130.0, 130.5, 132.3, 134.0, 134.8, 135.0, 158.3, 191.3. Anal. Calcd for $C_{18}H_{20}ClNO_2S$: C, 61.79, H, 5.76. Found: C, 62.03, H, 5.76.

(*S*)-2-(2-Aminophenyl)ethyl 2-(methallyloxy)thiobenzoate HCl salt (19) was prepared from **12** according to procedure B: white solid; mp 126.5−127 °C; ^{1}H NMR (CD_3OD) δ 1.89 (s, 3H), 3.02−3.08 (m, 2H), 3.23−3.28 (m, 2H), 4.60 (s, 2H), 5.00 (s, 1H), 5.15 (s, 1H), 7.02 (t, J = 7.6 Hz, 1H), 7.12 (d, J = 8.4 Hz, 1H), 7.40−7.54 (m, 5H), 7.75 (dd, J = 7.8, 1.7 Hz, 1H); ^{13}C NMR (CD_3OD) δ 19.9, 30.2, 31.9, 73.6, 114.0, 121.7, 125.0, 128.1, 129.6, 130.5, 130.5, 130.6, 130.7, 132.6, 135.3, 135.5, 142.0, 158.6, 193.1. Anal. Calcd for $C_{19}H_{22}ClNO_2S$: C, 62.71, H, 6.09. Found: C, 63.02, H, 6.12.

(*S*)-2-(2-Aminophenyl)ethyl 2-(propargyloxy)thiobenzoate HCl salt (20) was prepared from **13** according to procedure B: white solid; mp 137−138 °C; ^{1}H NMR (CD_3OD) δ 3.02−3.08 (m, 3H), 3.23−3.28 (m, 2H), 4.87 (d, J = 2.4 Hz, 2H), 7.08 (td, J = 8.0, 0.8 Hz, 1H), 7.25 (d, J = 8.2 Hz, 1H), 7.40−7.58 (m, 5H), 7.75 (dd, J = 7.8, 1.7 Hz, 1H); ^{13}C NMR (CD_3OD) δ 30.2, 31.9, 57.5, 77.8, 115.5, 122.6, 124.9, 128.8, 130.5, 130.6, 130.7, 132.7, 135.1, 135.5, 157.3, 193.2. Anal. Calcd for $C_{18}H_{18}ClNO_2S$: C, 62.15, H, 5.22. Found: C, 61.99, H, 5.33.

(*S*)-2-(2-Aminophenyl)ethyl 2-allylthiobenzoate HCl salt (21) was prepared from **14** according to procedure B: colorless oil; ^{1}H NMR (CD_3OD) δ 3.11−3.16 (m, 2H), 3.28−3.33 (m, 2H), 3.58 (d, J = 5.8 Hz, 2H), 5.00−5.06 (m, 2H), 5.90−6.03 (m, 1H), 7.35−7.61 (m, 7H), 7.77 (d, J = 8.0, 1H); ^{13}C NMR (CD_3OD) δ 29.9, 31.6, 38.2, 116.1, 124.5, 127.3, 129.3, 129.4, 130.1, 131.9, 132.4, 133.0, 134.7, 138.0, 138.5, 139.4, 195.9; HRMS calcd 297.1187, found 297.1187.

(*S*)-2-(2-Aminophenyl)ethyl 2-allyl-4-nitrothiobenzoate HCl salt (22) was prepared from **15** according to procedure B: white solid; mp 153−154 °C; ^{1}H NMR (CD_3OD) δ 2.94 (s, 2H), 3.15−3.20 (m, 2H), 3.39−3.44 (m, 2H), 3.68 (d, J = 6.5 Hz, 2H), 5.11 (s, 1H), 5.15 (dd, J = 8.0, 1.6 Hz, 1H), 5.96−6.05 (m, 1H), 7.41−7.63 (m, 4H), 7.97 (d, J = 8.2 Hz, 1H), 8.22 (dd, J = 9.6, 2.4 Hz, 1H); ^{13}C NMR (CD_3OD) δ 30.1, 31.2, 37.7, 117.6, 122.3, 124.5, 126.2, 129.5, 130.2, 130.3, 132.5, 134.5, 136.6, 141.5, 143.9, 150.7, 194.9. Anal. Calcd for $C_{18}H_{19}ClN_2O_3S$: C, 57.06, H, 5.05. Found:C, 56.53, H, 4.85.

(*S*)-2-(2-Aminophenyl)ethyl 2-allyl-5-methoxythiobenzoate HCl salt (23) was prepared from **16** according to procedure B: white solid; mp 124−125 °C; ^{1}H NMR (CD_3OD) δ 3.06−3.11 (m, 2H), 3.30−3.35 (m, 2H), 3.44 (d, J = 6.4 Hz, 2H), 3.80 (s, 3H), 4.93 (dd, J = 8.5, 1.5 Hz, 1H), 4.98 (s, 1H), 5.82−5.95 (m, 1H), 7.04 (dd, J = 8.5, 2.6 Hz, 1H), 7.19−7.22 (m, 2H), 7.37−7.48 (m, 3H), 7.55 (d, J = 8.1 Hz, 1H); ^{13}C NMR (CD_3OD) δ 29.9, 31.5, 37.3, 55.8, 114.7, 115.7, 118.2, 124.6, 129.4, 130.2, 130.4, 131.1, 132.5, 133.1, 134.9, 138.4, 139.3, 159.2, 195.7. Anal. Calcd for $C_{19}H_{22}ClNO_2S$: C, 62.71, H, 6.09. Found: C, 62.79, H, 6.14.

(*S*)-2-(2-Aminophenyl)ethyl 3,3-bis(ethoxycarbonyl)-5-hexenethioate HCl salt (24) was prepared from **17** according to procedure B: white solid; ^{1}H NMR (CD_3OD) δ 1.23 (t, J = 6.9 Hz, 6H), 2.68 (d, J = 7.3 Hz, 2H), 3.14−3.32 (m, 6H), 4.19 (q, J = 7.0 Hz, 4H), 5.06 (s, 1H), 5.10 (s, 1H), 5.53−5.64 (m, 1H), 7.33−7.38 (m, 3H), 7.62 (s, 1H), 10.44 (s, 2H); ^{13}C NMR (CD_3OD) δ 14.5, 29.7, 31.9, 38.6, 46.9, 57.3, 63.1, 120.7, 123.7, 129.1, 129.4, 129.7, 132.5, 133.5, 133.6, 171.2, 198.3. Anal. Calcd for $C_{20}H_{28}ClNO_5S$: C, 55.87, H, 6.56. Found: C, 56.07, H, 6.47.

Procedure C: Preparation of Diazonium Salts. A solution of the appropriate amine hydrochloride (0.1 mmol) and 48% HBF_4 (54 mg, 0.3 mmol) in EtOH (1 mL) at 0 °C was treated with isoamyl nitrite (20 mg, 0.17mmol). After 30 min, ether (5 mL) was added to the solution and stirring continued for another 30 min. A white solid was obtained by filtration and washed with cold water and ether several times. The solid was recrystallized from acetone/ether and isolated in the form of white or yellow crystals. No characterization, other than ^{1}H NMR spectroscopy, was attempted on these compounds which were used directly in the next step.

2-{2-[[2-(Allyloxy)benzoyl]thio]ethyl}benzenediazonium tetrafluoroborate (25) was prepared from **18** according to procedure C: yellow solid; ^{1}H NMR (CD_3COCD_3) δ 3.49−3.63 (m, 2H), 3.57−3.63 (m, 2H), 4.77 (dt, J = 5.1, 1.5 Hz, 2H), 5.30 (dq, J = 10.6, 1.5 Hz, 1H), 5.52 (dq, J = 17.2, 1.7 Hz, 1H), 6.09−6.18 (m, 1H), 7.08 (td, J = 7.1, 1.0 Hz, 1H), 7.22 (d, J = 8.4 Hz, 1H), 7.55−7.61 (m, 1H), 7.77 (dd, J = 15.5, 1.8 Hz, 1H), 7.98 (td, J = 7.8, 1.2 Hz, 1H), 8.12 (d, J = 8.0 Hz, 1H), 8.35 (td, J = 7.8, 1.3 Hz, 1H), 8.86 (dd, J = 8.4, 1.2 Hz, 1H).

2-{2-[[2-(Methallyloxy)benzoyl]thio]ethyl}benzenediazonium tetrafluoroborate (26) was prepared from **19** according to procedure C: white solid; ^{1}H NMR (CD_3COCD_3) δ 1.88 (s, 3H), 3.47−3.53 (m, 2H), 3.55−3.63 (m, 2H), 4.67 (s, 2H), 5.02 (s, 1H), 5.19 (s, 1H), 7.10 (td, J = 7.7, 1.0 Hz, 1H), 7.23 (d, J = 4.9 Hz, 1H), 7.57 (td, J = 7.3, 1.8 Hz, 1H), 7.77 (dd, J = 7.8, 1.8 Hz, 1H), 7.98 (td, J = 8.1, 1.1 Hz, 1H), 8.12

(d, J = 7.9 Hz, 1H), 8.36 (td, J = 7.8, 1.3 Hz, 1H), 8.86 (dd, J = 8.4, 1.1 Hz, 1H).

2-{2-[[2-(Propargyloxy)benzoyl]thio]ethyl}benzenediazonium tetrafluoroborate (27) was prepared from **20** according to procedure C: white solid; ^{1}H NMR (CD_3COCD_3) δ 3.21 (t, J = 2.4 Hz, 1H), 3.47−3.53 (m, 2H), 3.58−3.64 (m, 2H), 4.98 (d, J = 2.4 Hz, 2H), 7.14 (td, J = 6.9, 0.8 Hz, 1H), 7.33 (d, J = 8.4 Hz, 1H), 7.63 (td, J = 8.7, 1.7 Hz, 1H), 7.77 (dd, J = 7.8, 1.8 Hz, 1H), 7.99 (t, J = 8.4 Hz, 1H), 8.14 (d, J = 7.5 Hz, 1H), 8.37 (td, J = 7.8, 1.1 Hz, 1H), 8.87 (d, J = 8.4 Hz, 1H).

2-[2-[(2-Allylbenzoyl)thio]ethyl]benzenediazonium tetrafluoroborate (28) was prepared from **21** according to procedure C: white solid; ^{1}H NMR (CD_3COCD_3) δ 3.54−3.59 (m, 4H), 3.60−3.68 (m, 2H), 5.00−5.06 (m, 2H), 5.89−6.00 (m, 1H), 7.38 (td, J = 7.6, 1.3 Hz, 1H), 7.56 (td, J = 7.5, 1.9 Hz, 1H), 7.79 (dd, J = 8.7, 1.5 Hz, 1H), 8.00 (td, J = 8.5, 1.2 Hz, 1H), 8.14 (dd, J = 7.9, 0.7 Hz, 1H), 8.37 (td, J = 7.7, 1.3 Hz, 1H), 8.86 (dd, J = 8.4, 1.2 Hz, 1H).

2-[2-[(2-Allyl-4-nitrobenzoyl)thio]ethyl]benzenediazonium tetrafluoroborate (29) was prepared from **22** according to procedure C: white solid; ^{1}H NMR (CD_3COCD_3) δ 3.45−3.57 (m, 4H), 3.62 (d, J = 6.4 Hz, 2H), 5.03−5.19 (m, 2H), 5.89−5.99 (m, 1H), 7.85 (t, J = 7.5 Hz, 1H), 7.95 (dd, J = 9.2, 3.0 Hz, 1H), 8.01 (d, J = 7.9 Hz, 1H), 8.15−8.27 (m, 3H), 8.65 (d, J = 8.4 Hz, 1H).

2-[2-[(2-Allyl-5-methoxybenzoyl)thio]ethyl]benzenediazonium tetrafluoroborate (30) was prepared from **23** according to procedure C: white solid; ^{1}H NMR (CD_3COCD_3) δ 3.43−3.46 (m, 6H), 3.82 (s, 3H), 4.90−4.98 (m, 2H), 5.81−5.95 (m, 1H), 7.08 (dd, J = 8.5, 2.7 Hz, 1H), 7.22−7.26 (m, 2H), 7.86 (t, J = 8.1 Hz, 1H), 7.99 (d, J = 7.9 Hz, 1H), 8.23 (t, J = 7.8 Hz, 1H), 8.63 (d, J = 8.3 Hz, 1H).

2-{2-[[3,3-Bis(ethoxycarbonyl)-5-hexenoyl]thio]ethyl}benzenediazonium tetrafluoroborate (31) was prepared from **24** according to procedure C: yellow oil; ^{1}H NMR (CD_3COCD_3) δ 1.23 (t, J = 7.1 Hz, 6H), 2.67 (d, J = 7.5 Hz, 2H), 3.21 (s, 2H), 3.39−3.44 (m, 2H), 3.49−3.54 (m, 2H), 4.16 (q, J = 7.1 Hz, 4H), 5.10 (s, 1H), 5.15 (d, J = 4.3 Hz, 1H), 5.63−5.74 (m, 1H), 7.97 (t, J = 8.5 Hz, 1H), 8.06 (d, J = 7.4 Hz, 1H), 8.33 (td, J = 7.8, 1.2 Hz, 1H), 8.83 (dd, J = 8.4, 1.1 Hz, 1H).

Procedure D: Reaction of 25−31 with NaI. NaI (27 mg, 0.18 mmol) in redistilled, degassed acetone (1 mL) was added dropwise under Ar into a solution of the diazonium salt (60 mg, 0.15 mmol) in redistilled, degassed acetone (50 mL) at room temperature. After the addition, the reaction mixture was stirred for 6 h at room temperature. Removal of the volatiles and preparative TLC or column chromatography on silica gel enabled isolation of the various products as indicated in Table 1.

3-Methylenechromanone (32):[17] ^{1}H NMR δ 5.01 (dd, J = 1.5, 1.3 Hz, 1H), 5.58 (dt, J = 1.5, 1.1 Hz, 1H), 6.32 (dt, J = 1.3, 1.1 Hz, 1H), 6.98 (dd, J = 8.4, 0.9 Hz, 1H), 7.06 (ddd, J = 8.0, 7.8, 0.9 Hz, 1H), 7.49 (ddd, J = 8.4, 7.8, 1.8 Hz, 1H), 7.99 (dd, J = 8.0, 1.8 Hz, 1H).

2,3-Dihydrobenzothiophene (33):[2] ^{1}H NMR δ 3.27−3.38 (m, 4H), 7.00 (t, J = 7.3 Hz, 1H), 7.11 (t, J = 7.3 Hz, 1H), 7.20 (t, J = 8.2 Hz, 1H).

3-(Iodomethyl)-3-methylchromanone (34): colorless oil; ^{1}H NMR δ 1.27 (s, 3H), 3.27 (d, J = 10.4 Hz, 1H), 3.55 (d, J = 10.4 Hz, 1H), 4.18 (d, J = 11.7 Hz, 1H), 4.40 (d, J = 11.7 Hz, 1H), 6.97 (dd, J = 7.4, 0.7 Hz, 1H), 7.04 (td, J = 8.0, 1.0 Hz, 1H), 7.50 (td, J = 7.6, 1.8 Hz, 1H), 7.90 (dq, J = 7.9, 0.3 Hz, 1H); ^{13}C NMR δ 10.0, 19.1, 44.6, 75.5, 117.8, 119.2, 127.8, 136.1, 161.0, 192.4; HRMS calcd 301.9763, found 301.9803.

3-(Iodomethylene)chromanone (35): colorless oil; ^{1}H NMR δ 5.07 (d, J = 1.8 Hz, 2H), 7.00 (d, J = 8.4 Hz, 1H), 7.07 (t, J = 7.9 Hz, 1H), 7.51 (td, J = 7.2, 1.2 Hz, 1H), 7.98 (dd, J = 7.9, 1.5 Hz, 1H), 8.05 (t, J = 1.7 Hz, 1H); ^{13}C NMR δ 73.0, 97.0, 118.1, 120.4, 122.2, 128.0, 136.4, 141.6, 161.6, 178.1; HRMS calcd 285.9450, found 285.9490.

3-Methyleneindanone (36):[17] ^{1}H NMR ($CDCl_3$) δ 3.75 (s, 2H), 5.65 (s, 1H), 6.37 (s, 1H), 7.38 (t, J = 7.7 Hz, 1H), 7.48 (d, J = 5.0 Hz, 1H), 7.60 (t, J = 5.0 Hz, 1H), 7.85 (d, J = 7.7 Hz, 1H).

3-(Iodomethyl)-1-isochromanone (37):[30] ^{1}H NMR δ 3.13 (dd, J = 16.1, 10.4 Hz, 1H), 3.23 (dd, J = 16.2, 3.7 Hz, 1H), 3.42 (dd, J = 10.5, 7.2 Hz, 1H), 3.52 (dd, J = 10.5, 4.6 Hz, 1H), 4.52−4.62 (m, 1H), 7.28 (d, J = 7.6Hz, 1H), 7.42(t, J = 7.7 Hz, 1H), 7.57 (t, J = 7.7Hz, 1H), 8.10 (d, J = 7.7Hz, 1H).

6-Nitro-1-naphthol (39): yellow solid; mp 165−167 °C, lit.[31] mp 181−182 °C; ^{1}H NMR δ 5.51 (s, 1H), 7.01 (dd, J = 7.5, 0.9 Hz, 1H), 7.47 (t, J = 7.6 Hz, 1H), 7.63 (d, J = 8.3 Hz, 1H), 8.22 (dd, J = 9.2, 2.2 Hz, 1H), 8.35 (d, J = 9.2 Hz, 1H), 8.76 (d, J = 2.2 Hz, 1H).

3-(Iodomethyl)-6-nitroisochromanone (40): yellow solid; mp 120−122 °C; ^{1}H NMR δ 3.25 (dd, J = 16.5, 10.8 Hz, 1H), 3.38 (dd, J = 16.5, 3.5 Hz, 1H), 3.45 (dd, J = 10.7, 7.1 Hz, 1H), 3.55 (dd, J = 10.7, 4.5 Hz, 1H), 4.57−4.65 (m, 1H), 8.18 (s, 1H), 8.26 (d, J = 8.5 Hz, 1H), 8.30 (d, J = 8.5 Hz, 1H); ^{13}C NMR δ 4.8, 33.4, 123.1, 129.7, 132.2, 139.7, 151.0, 162.6; HRMS calcd 332.9457, found 332.9497.

2-Methylene-6-methoxyindanone (41): pale yellow oil; ^{1}H NMR δ 3.68 (s, 2H), 3.85 (s, 3H), 5.62 (dt, J = 1.7, 0.9 Hz, 1H), 6.35 (dt, J = 3.5, 0.8 Hz, 1H), 7.20 (dd, J = 8.4, 2.6 Hz, 1H), 7.30 (d, J = 2.5 Hz, 1H), 7.38 (d, J = 8.4 Hz, 1H); ^{13}C NMR δ 31.0, 55.5, 105.7, 119.1, 124.2, 127.0, 139.4, 142.9, 144.0, 159.4, 193.3. Anal. Calcd for $C_{11}H_{10}O_2$: C, 75.50, H, 5.76. Found: C, 75.60, H, 6.01.

4,4-Bis(ethoxycarbonyl)-2-methylenecyclopentanone (42): colorless oil; ^{1}H NMR δ 1.27 (t, J = 7.1 Hz, 6H), 2.91 (s, 2H), 3.24 (t, J = 2.5 Hz, 2H), 4.22 (q, J = 7.1 Hz, 1H), 5.42 (q, J = 1.7 Hz, 1H), 6.07 (q, J =2.0 Hz, 1H); ^{13}C NMR δ 13.9, 36.8, 45.0, 54.0, 62.1, 118.9, 141.4, 170.5, 201.4; HRMS calcd 240.0998, found 240.0998.

Cyclization of 2-Allylbenzoic Acid with Iodosobenzene Diacetate: 3-(Iodomethyl)isochromanone (40). Iodosobenzene diacetate (71 mg, 0.22 mmol) and iodine (71 mg, 0.3 mmol) were added to a solution of 2-allylbenzoic acid (33 mg, 0.2 mmol) in acetone (5 mL) and the mixture irradiated through Pyrex in a Rayonet photoreactor (254 nm) with stirring for 1 h at room temperature. Removal of the solvent followed by chromatography on a silica gel gave **40** (55 mg, 95%) identical with the sample isolated above.

Reaction of 25 with CuCN: 3-(Cyanomethyl)chromanone (54) and 3-Methylchromanone (55). A solution of CuCN (11 mg, 0.12 mmol) in DMSO (1 mL) was added dropwise to a solution of **25** (40 mg, 0.1 mmol) in DMSO (20 mL). After addition was complete the reaction mixture was stirred for 12 h before brine (50 mL) was added and the mixture was extracted with EtOAc (3 × 20 mL). The combined extracts were washed with water and brine and dried. After removal of the solvent, purification by column chromatography on silica gel (eluent: first CH_2Cl_2/hexane, 1:1; then CH_2Cl_2/EtOAc, 9:1) gave **54** as a colorless oil (6.7 mg, 36%), **55** (2 mg, 12%), and **32** (2 mg, 12%). **54:** ^{1}H NMR δ 2.60 (dd, J = 17.3, 9.1 Hz, 1H), 3.00 (dd, J = 17.3, 4.6 Hz, 1H), 3.14−3.23 (m, 1H), 4.35 (t, J = 11.7 Hz, 1H), 4.75 (dd, J = 11.4, 5.2 Hz, 1H), 7.02 (d, J = 8.5 Hz, 1H), 7.07 (t, J = 8.0 Hz, 1H), 7.53 (td, J = 7.2, 1.7 Hz, 1H), 7.90 (dd, J = 7.9, 1.8 Hz, 1H); ^{13}C NMR δ 14.1, 42.0, 69.4, 117.1, 117.9, 119.8, 122.0, 127.4, 136.6, 161.6, 190.0; HRMS calcd 187.0633, found 187.0633. **55:**[2] ^{1}H NMR δ 1.23 (d, J = 7.0 Hz, 3H), 2.83−2.91 (m, 1H), 4.16 (t, J = 11.2 Hz, 1H), 4.51 (dd, J = 11.3, 5.1 Hz, 1H), 6.96 (d, J = 8.8 Hz, 1H), 7.02 (t, J =7.0 Hz, 1H), 7.47 (td, J = 9.0, 1.8 Hz, 1H), 7.90 (dd, J = 7.8, 1.7 Hz, 1H).

Reaction of 26 with PhSNa: 3-Methyl-3-((phenylthio)methyl)chromanone (56). A solution of PhSNa (0.184 mmol) in DMSO (0.5 mL) was added to a solution of **26** (52 mg, 0.12mmol) in DMSO (15 mL) at room temperature and the mixture stirred under Ar for 6 h. After extractive workup the residue was separated by column chromatography on silica gel (eluent: CH_2Cl_2/hexane, 2:1), giving **56**, a pale yellow oil (12 mg, 35%), as the only significant cyclized product: ^{1}H NMR δ 1.27 (s, 3H), 3.20 (d, J = 13.4 Hz, 1H), 3.31 (d, J = 13.4 Hz, 1H), 4.18 (d, J = 11.6 Hz, 1H), 4.49 (d, J = 11.6 Hz, 1H), 6.95 (dd, J = 8.3, 0.7 Hz, 1H), 7.03 (td, J = 7.2, 1.1 Hz, 1H), 7.20

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(d, J = 7.2 Hz, 1H), 7.24−7.30 (m, 2H), 7.40 (dd, J = 8.5, 1.5 Hz, 1H), 7.48 (td, J = 7.1, 1.2 Hz, 1H), 7.92 (dd, J = 7.7, 0.7 Hz, 1H); ^{13}C NMR δ 18.0, 38.8, 46.5, 74.0, 118.0, 119.7, 121.9, 126.8, 128.1, 129.2, 130.2, 136.2, 136.8, 161.3, 195.5. Anal. Calcd for $C_{17}H_{16}O_2S$: C, 71.80, H, 5.67. Found: C, 71.60, H, 5.57.

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Supporting Information Available: Protocols for the synthesis of **7**−**10**, ^{1}H NMR spectra for diazonium salts **25**−**31**, and ^{1}H and ^{13}C NMR spectra for **21**, **34**, **35**, **40**, **42**, and **54** (22 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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