JOC The Journal of Organic Chemistry

Article

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Synthesis of Disubstituted Dithioethers: *tert*-Butoxide Promoted Elimination/Ring Opening of 1,3-Dithianes Followed by Palladium-Catalyzed C–S Bond Formation

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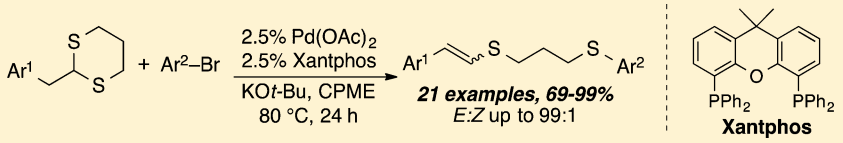
Supporting Information



ABSTRACT: We report the tandem base-promoted elimination/ring-opening of 2-benzyl-1,3-dithianes with subsequent cross coupling of the pendent thiol with a range of aryl bromides. A simple $Pd(OAc)_2$/Xantphos catalyst system affects this new reaction and is compatible with a wide range of functional groups, including heteroaromatic coupling partners. The transformation proceeds in good to excellent yields (69–99%) and exhibits strong stereoselectivity, forming the *E*-alkene as the major diastereomer. This new methodology provides access to nonsymmetric propylene styryl/aryl dithioethers, a previously undisclosed motif.

INTRODUCTION

Vinyl sulfides are useful synthetic building blocks for organic chemists. For example, these motifs can be used as Michael acceptors,[1] as surrogates for enol ethers,[2−5] and in cycloaddition reactions.[6−8] Additionally, vinyl sulfides see utility as a pseudohalide electrophile in transition metal C−C bond forming reactions, predominantly with boron nucleophiles.[9−12]

Vinyl sulfides are found in natural products that exhibit desirable biological activities,[13−15] making this motif an attractive target for the development of new synthetic approaches (Figure 1). Over the years, a range of routes for accessing vinyl sulfides have been developed, though nucleophilic substitution via an addition−elimination pathway is most prevalent. Either vinyl halide electrophiles or the corresponding alkyne directly can be reacted with sulfur nucleophiles. Although these conditions generally require harsh conditions and are limited to a narrow range of activated electrophiles, recent strides employing transition metal catalysts have allowed for milder reaction conditions to be employed, accessing vinyl thioethers from a range of vinyl or acetylene electrophiles.[16−23] This is significant as it affords the synthetic chemist a route to this important functional class even when unactivated alkynes or vinyl bromides are necessary, namely, ones that cannot stabilize the strong carbanionic character that typifies the addition/elimination pathway.

Similarly, aryl sulfides are an important motif found in a range of small molecule therapeutics that show promise for treating, for example, inflammatory and immune diseases,[24] Parkinson's and Alzheimer's Diseases,[25] HIV,[26] and breast cancer.[27] In 1980, Migita and co-workers first reported the palladium-catalyzed cross-coupling of aryl iodides with various sulfur nucleophiles to afford aryl thioethers.[28] In large part due to the significant advances of transition-metal catalyzed chemistry,[29−31] there has been extensive development of robust and reliable routes to aryl sulfides mediated by transition metal catalysts.[32,33] Continued improvements to this important methodology have expanded the scope of aryl electrophiles to include bromide, chloride, and triflate electrophiles. Palladium- and nickel-based catalysts have been used most widely, though alternative catalysts, such as copper,[34] have seen recent adaptation as they offer the advantages of lower price and toxicity. Aside from traditional cross-coupling approaches, methods have been developed that couple disulfides with, for example, aryl iodides,[35] aryl boronic acids,[36] and aryl siloxanes[37] in the presence of a stoichiometric reducing agent and copper catalyst. Recently, noncatalytic examples have illustrated that sulfenyl chlorides react with either magnesium-[38] or zinc-based[39] nucleophiles to access this important substrate class. Thus, the value of the aryl sulfide motif continues to stimulate significant interest, including the development of alternative approaches to this compound class.

In 2014, our group[40] and the Walsh[41] group independently disclosed that 2-aryl-1,3-dithianes act as competent, polarity-reversed transmetalation reagents in palladium-catalyzed cross-coupling reactions. During our initial investigations, we applied our cross-coupling conditions to 2-benzyl-1,3-dithiane (**5**) to probe the ability of the one-carbon homologue to undergo cross coupling (Scheme 1). Though none of the expected cross-coupling product was observed, we found that the starting materials were consumed completely and converted cleanly to a new product (**6**).

Received: March 11, 2015
Published: March 30, 2015

DOI: 10.1021/acs.joc.5b00547
J. Org. Chem. 2015, 80, 4123−4131

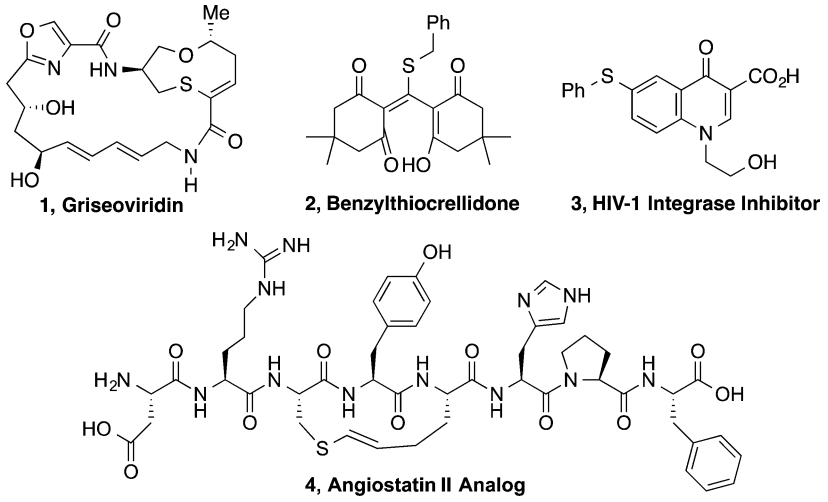


Figure 1. Examples of biologically interesting vinyl and aryl thioethers.

Scheme 1. Discovery of Tandem Elimination/Ring-Opening/C−S Cross Coupling

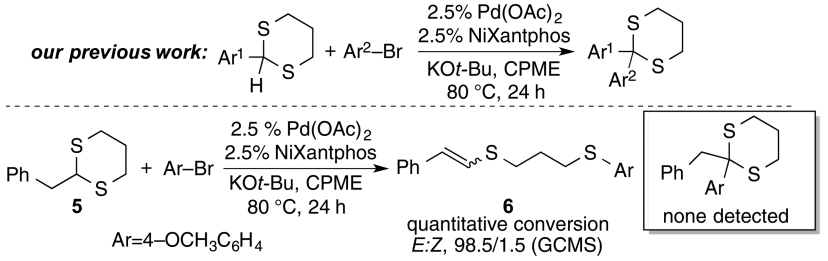
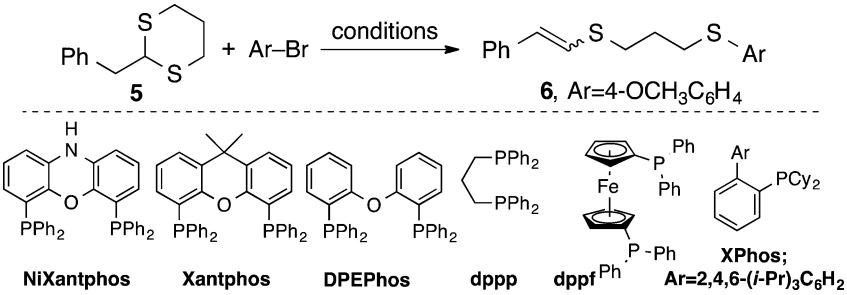


Table 1. Reaction Optimization[a]



entry	ligand	base	solvent	cat. %	t (°C)	yield (%)[b]
1	NiXantphos	KOtBu	1,4-Dioxane	2.5	80	100
2	Xantphos	KOtBu	1,4-Dioxane	2.5	80	100
3	dppp	KOtBu	1,4-Dioxane	2.5	80	0
4	dppf	KOtBu	1,4-Dioxane	2.5	80	56
5	DPEPhos	KOtBu	1,4-Dioxane	2.5	80	0
6	XPhos	KOtBu	1,4-Dioxane	2.5	80	trace
7	Xantphos	KOtBu	CPME	2.5	80	100
8	Xantphos	KOtBu	CPME	1.0	80	100
9	Xantphos	KOtBu	CPME	2.5	60	23
10	Xantphos	KOtBu	CPME	1.0	60	20
11	Xantphos	KOtBu	CPME	2.5	25	0
12	Xantphos	KOtBu	CPME	1.0	25	0
13	Xantphos	LiHMDS	CPME	2.5	80	0

[a]Reactions run on a 1.0 mmol scale, 1:1 aryl bromide/benzyl dithiane, 0.2 M in the indicated solvent. Three equiv of base was used. $Pd(OAc)_2$ and bidentate ligands dosed in a 1:1 ratio at the indicated catalyst loading. For monodentate XPhos, 5% of the ligand (2:1 L/Pd) was dosed. [b]Yield extrapolated from GC area % of the peak for **6**.

This tandem base-promoted elimination with ring opening followed by palladium-catalyzed C−S bond formation affords a previously undisclosed chemical motif. Over the past decades, there have been a handful of reports detailing the ring

DOI: 10.1021/acs.joc.5b00547
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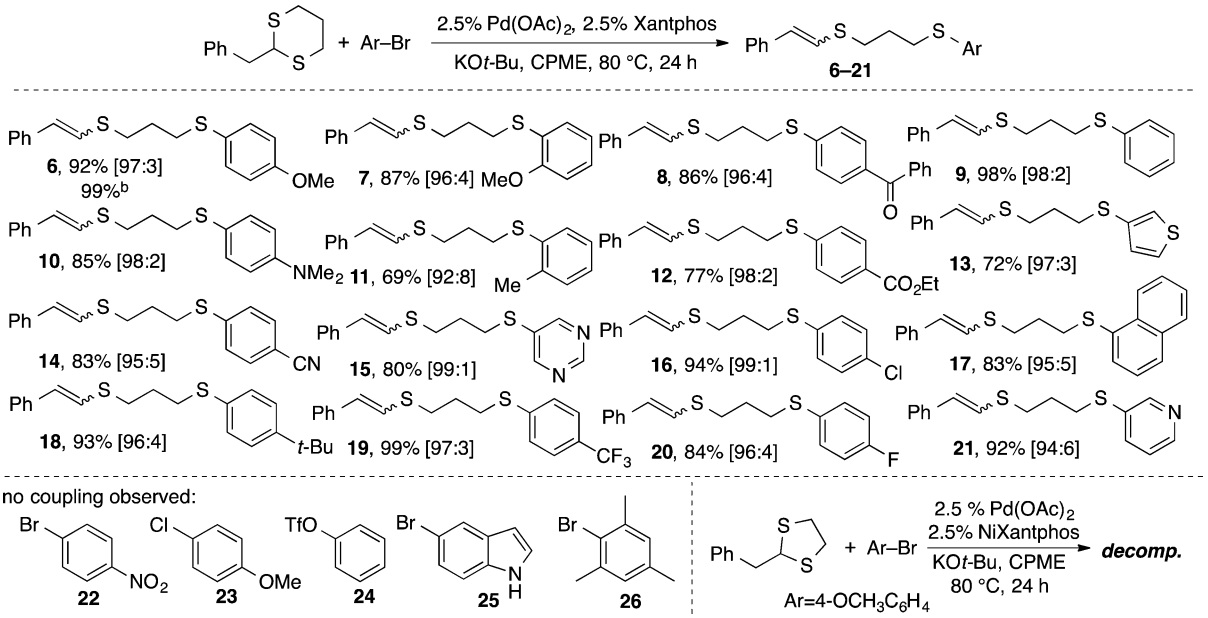
Scheme 2. Reactivity of Aryl and Herteroaryl Bromides[a]



[a]Reactions run on a 1.0 mmol scale at 0.2 M. Yield refers to yield of *E:Z* mixture in the bracketed ratio that is otherwise analytically pure. *E:Z* ratio determined by the uncorrected relative peak integrations of the GC trace, which were confirmed by the relative integrations for the vinyl protons in the ^{1}H NMR. [b]Run on a 5.0 mmol scale.

opening[42] or the ring expansion[43,44] of 1,3-dithiolanes to afford vinyl sulfides. Additionally, we could find a single example reporting the base-mediated ring opening of 1,3-dithianes[45] when adjacent to an ether.[46] Though no examples of the resulting propylene-linked styryl-aryl dithioether have been reported, dithioethers are known to be excellent chelators of aqueous mercury ions.[47] Taken together with the prevalence of both aryl thioethers and vinyl thioethers in biologically active small molecules, we felt this new transformation warranted further examination. The wide availability of commercially available aryl bromides should allow for a diverse range of interesting new substrates to be synthesized, and we sought to explore the scope and limitations of this new reaction.

RESULTS AND DISCUSSION

Though our initial discovery led to isolation of the title compound in quantitative yield, we sought to screen for improved reaction conditions before probing the limitations of this chemistry. Of special importance is to examine the impact of lower palladium and ligand loading and to search out alternative ligands to replace the relatively expensive NiXantphos.

We were pleased to find that substituting the less expensive Xantphos led to no observed loss of reactivity.[48] Dppf also provided some of the desired transformation but ultimately proved to be less capable than Xantphos. Other bisphosphine ligands, as well as the monodentate XPhos, showed little to no conversion to product. The less toxic CPME replaced 1,4-dioxane with no negative impact on reactivity (Table 1, entry 7). Next, 80 °C proved optimal as lowering the temperature to 60 °C led to sluggish reactivity and incomplete conversion after 24 h (Table 1, entries 9 and 10). Running the reaction at room temperature returned only starting materials, and substituting LiHMDS for *tert*-butoxide furnished none of the target compound. During this initial reaction optimization, we did find that catalyst loading could be lowered to 1% for both palladium and Xantphos ligand with no observed loss of reactivity (Table 1, entry 8). However, as we began our substrate screening, 2.5% catalyst loading gave far more consistent results and complete conversion of starting materials. As such, we opted to continue with 2.5% catalyst loading.

With these optimized conditions in hand, we began to screen the chemistry against a wide variety of aryl bromides. Electronics of the aryl bromide seemed to have little impact upon the observed reactivity of the system. Both electron-rich and -poor aryl bromides reacted cleanly with no loss of catalytic activity. Reacting **5** with 4-bromoanisole led to the isolation of **6** in 92% yield, and **10** was isolated in 85% yield when employing the even more electron-rich 4-bromo-*N,N*-dimethylaniline. Similarly, examples of the electron withdrawing ketone, ester, nitrile, and trifluoromethyl groups at the para position of aryl bromides led to high yields for **8** (86%), **12** (77%), **14** (83%), and **19** (99%), respectively. A limitation was met when running the reaction with 4-nitrobromobenzene (**22**). In this case, only decomposition was observed, and the reaction went without detection of any of the desired product. Attempts to lower the reaction temperature did not improve the outcome. The reaction tolerated the presence of aryl chlorides, and **16** was isolated in 94% yield with the carbon−chlorine bond still intact. Repeated attempts were made to react either aryl triflate (e.g., **24**) or aryl chloride (e.g., **23**) electrophiles as alternatives to the aryl bromide in this cross coupling, though they were met without success.[49] Pyridine- and pyrimidine-derived aryl bromides were well tolerated, providing **21** (from 3-bromopyridine) and **15** (from 5-bromopyrimidine) in 92 and 80% yields, respectively. A notable current limitation of this chemistry is the inability of the unprotected 5-bromoindole (**25**) to engage. Finally, substitution at the ortho position was well tolerated (**7**, **11**, **17**), though the methodology met its steric limitations when subjecting 2-bromomesitylene **26** to the reaction conditions, as no cross-coupling product was observed.[50] Across the substrates examined, the *E:Z* ratio was

DOI: 10.1021/acs.joc.5b00547
J. Org. Chem. 2015, 80, 4123−4131

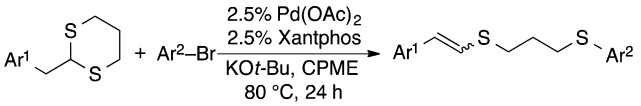
high save for the case of 2-bromotoluene to yield **11**. Still, the observed 92:8 ratio would likely be synthetically useful. Our initial attempts to engage 2-benzyl-1,3-dithiolane in the reaction to afford ethylene-linked styryl-aryl dithioether have been met without success. When subjecting the five-membered dithiolane ring to our standard conditions, a very messy crude reaction mixture was observed, and GC analysis found no mass that corresponded to the expected product. The tendency of 1,3-dithiolanes to act differently under strongly basic conditions than their 1,3-dithiane analogues, and their known tendency to undergo decomposition/fragmentation in various ways has been reported.[51,52] However, work is ongoing in our lab generate similar reactivity from 1,3-dithiolane.

The chemistry scaled cleanly to the gram scale, and compound **6** was isolated in quantitative yield when the reaction was run at the 5.0 mmol scale with 2.5% catalyst loading. A standard aqueous/organic partition followed by running the crude reaction through a short plug of silica gel to remove the palladium catalyst was the only purification needed.

Next, we prepared derivatives of 2-benzyl-1,3-dithiane to ascertain what impact, if any, there was on reactivity. As Table 2 illustrates, no loss in yield was observed when cross-coupling the 2-F, 4-F, or 4-OMe phenyl derivatives of the dithiane with either 4-bromoanisole or 3-bromopyridine. For the most part, the observed *E:Z* ratio was on par with those observed in the unsubstituted variants, though it was noted that some erosion of selectivity was observed when the electron-releasing methyl ether was a part of the benzyl dithiane coupling partner (**34**; Table 2, entry 5). Currently, we speculate that this loss of selectivity might be attributed to attenuated acidity that would be expected at the benzylic position when it is part of an electron-rich arene.

Seeing the potential impact of acidity at the benzylic position upon the desired outcome, we prepared additional coupling substrates for further investigation. First, dithianes **36** and **37** were prepared to ascertain whether the methodology could be applied to substrates in which initial deprotonation occurred at positions other than the electronically favorable benzylic position. Indeed, it appears the acidity of the methyl C–H is not sufficient, as neither of these substrates underwent the expected transformation because only starting materials were obtained when subjected to the reaction conditions. 2-phenethyl-1,3-dithiane **38** also returned only starting materials under our reaction conditions, further illustrating the importance of pK_a in this transformation.

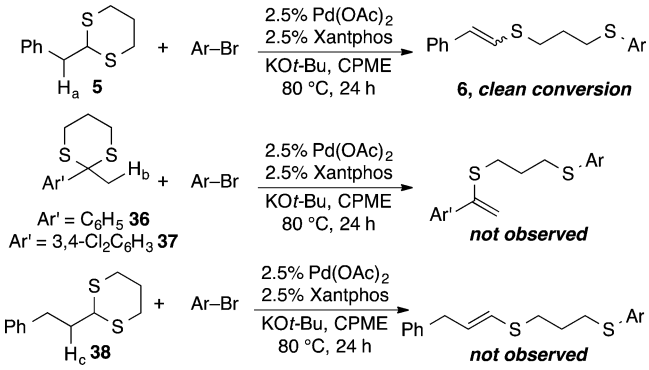
Table 2. Substitution of the 2-Benzyl-1,3-dithiane[a]



entry	Ar^1	Ar^2	product	yield (%)	*E:Z*
1	2-FC_6H_4 (**27**)	4-$MeOC_6H_4$	**30**	89	99:1
2	2-FC_6H_4 (**27**)	3-py	**31**	92	98.5:1.5
3	4-FC_6H_4 (**28**)	4-$MeOC_6H_4$	**32**	90	97:3
4	4-FC_6H_4 (**28**)	3-py	**33**	83	92:8
5	4-$MeOC_6H_4$ (**29**)	4-$MeOC_6H_4$	**34**	81	82:18

[a]Reactions run on a 1.0 mmol scale at 0.2 M. Yield refers to yield of *E:Z* mixture. *E:Z* ratio determined by uncorrected relative peak integrations of the GC trace.

Scheme 3. Role of pKa[a]



[a]All reactions run using 4-bromoanisole, Ar = 4-$OCH_3C_6H_4$

Mechanistically, we envisioned two possible routes for the elimination/ring-opening/C–S bond-forming event (Figure 2). Route 1 outlines the convergence of two mechanisms occurring in parallel: *tert*-butoxide-mediated elimination/ring-opening to generate the thiolate anion, which then intercepts the traditional Pd^0/Pd^{II} catalytic cycle. Alternatively, we entertained the possibility shown in Route 2, where the thiophilic palladium(II) complex would perhaps coordinate to a sulfur

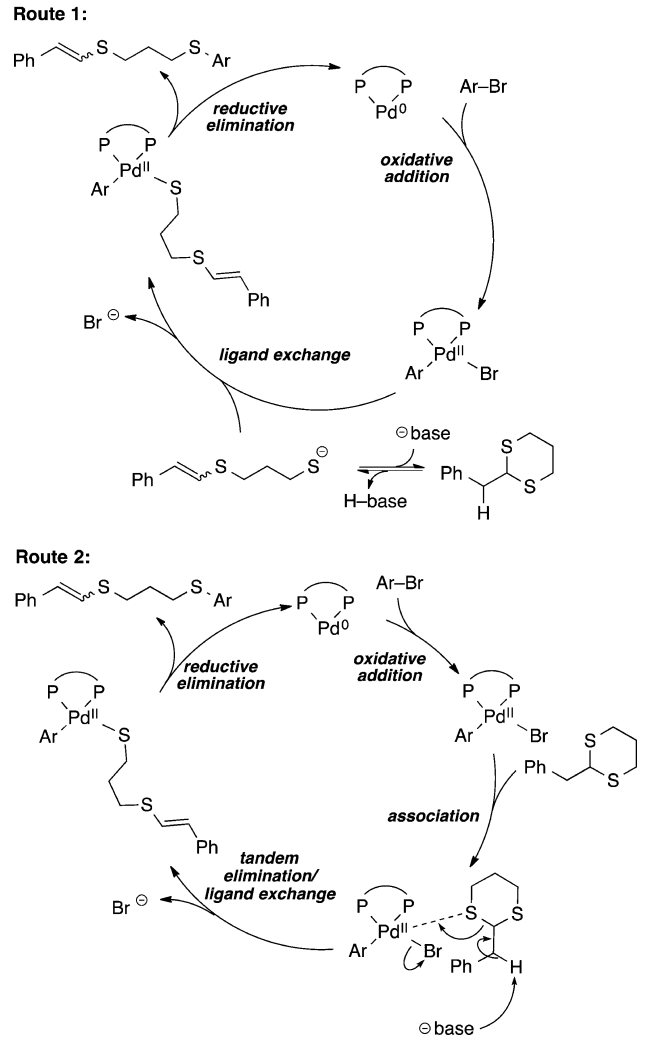


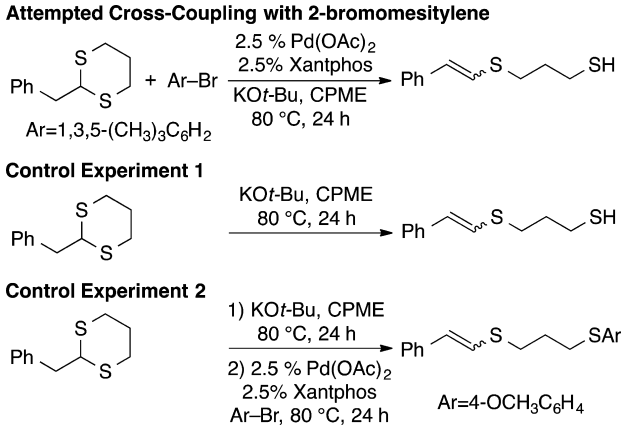
Figure 2. Two potential mechanistic routes.

DOI: 10.1021/acs.joc.5b00547
J. Org. Chem. 2015, 80, 4123–4131

atom of the dithiane. We reasoned that this might enhance the acidity of the benzylic proton at which point the *tert*-butoxide would promote tandem elimination/ring-opening/ligand exchange onto palladium. Both catalytic cycles finish with reductive elimination to regenerate the active Pd^0 catalyst.

We already had some inferred evidence that led us to favor Route 1. As mentioned above, the attempted cross coupling using 2-bromomesitylene led to clean recovery of the aryl bromide starting material along with the free, ring-opened thiol. We followed up this observation with two control experiments. First, a solution of the benzyl dithiane and potassium *tert*-butoxide in CPME was heated to 80 °C for 24 h. These conditions cleanly yielded the ring-opened thiol, illustrating that no additional activation by coordination to palladium is necessary to promote the ring opening step.[53] Our second control experiment was a two-step procedure that first subjected the 2-benzyl-1,3-dithiane to the basic conditions in the absence of catalyst and aryl bromide, then dosing in 4-bromoanisole, palladium, and ligand, and then allowing the mixture to age for 24 h at 80 °C. After this two-step sequence, product **6** was isolated in quantitative yield. At this point, we cannot exclude Route 2 as a competing catalytic cycle that also generates the desired compound, but all control experiments to date indicate that Route 1 is the more reasonable mechanism.

Scheme 4. Control Experiments



CONCLUSION

We have developed a novel C–S cross-coupling reaction that traps ring opened 2-benzyl-1,3-dithianes to afford *S*-styryl/*S*-aryl dithioethers under palladium catalysis. This sequence tolerates a wide range of aryl and heteroaryl bromides, proceeds very cleanly, and provides the title compounds in good-to-excellent yields. Most title compounds were isolated without extensive chromatography, simply passing the crude reaction mixture through a plug of silica to remove ligated palladium impurities. The reaction proceeds with high *E*-selectivity of the vinyl sulfides, and the clean, high-yielding nature of the methodology makes isolation and purification simple. Currently, our group is investigating alternatives to 2-benzyl-1,3-dithianes (e.g., 1,3-dithiolanes, 1,3-oxathiolanes, etc.) to engage in a similar reaction manifold. Additionally, alternative electron withdrawing groups (e.g., nitrile, ester, etc.) might be substituted for the phenyl ring and elicit similar electronic effects, affording access to a diverse collection of these vinyl sulfides. These investigations are already underway and will be reported in due course.

EXPERIMENTAL SECTION

General. Unless otherwise indicated, all reactions were prepared in a glovebox under a nitrogen atmosphere in 2-dram (8 mL) vials fit with Teflon-coated stir bars and sealed with a Teflon-lined cap. Once prepared, the vials were removed from the glovebox and placed on a thermostat-controlled aluminum heating block set to the desired temperature. All solvents, aryl halides, $Pd(OAc)_2$, and the 1,3-dithianes used in the synthesis of compounds **27**–**31** were purchased from commercial suppliers and used without further purification. *n*-Butyllithium was purchased as a 2.5 M solution in hexane and used as received. NiXantphos and Xantphos were purchased commercially and used as received.

Thin layer chromatography was carried out on silica gel plates, and eluted plates were visualized with UV light (254 nm) and/or $KMnO_4$ stain. Flash chromatography was carried out on silica gel (230–400 mesh). All yields refer to the isolated mixture of *E*:*Z* isomers that are otherwise analytically pure. ^1H and ^{13}C NMR spectra were recorded on a 400 MHz (400 MHz ^1H, 100 MHz ^{13}C) instrument. Spectra are reported in ppm and referenced to residual solvent $CHCl_3$ (7.28 ppm). ^1H NMR data are presented as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, etc.), coupling constant(s) in hertz (Hz), and integration. ^{13}C NMR data are reported in ppm relative to the solvent signal $CDCl_3$ (77.2 ppm). Data were collected at 25 °C. Infrared spectral data (neat) are reported in terms of frequency of absorption (cm^{-1}). Low resolution, electron impact (EI) mass spectral data are presented as follows: mass ion peak (relative intensity). For high-resolution mass spectral data, the sample mass was recorded on a high-resolution time-of-flight mass spectrometer using liquid injection field desorption ionization (LIFDI). The analyte was applied to the filament in ethyl acetate and/or dichloromethane. The solvent was allowed to evaporate before ramping to a 12K voltage field and ramping the filament current from zero to 85 mA. All samples were ionized at 0–40 mA with peak ion counts of ~0–25 mA. Chloropentafluorobenzene was used as an internal standard locking the peak at 201.9605 Da. Data is reported as follows: expected mass, actual mass, error (in mDa).

*Synthesis of 2-Benzyl-1,3-dithiane (**5**).* A dry 100 mL round-bottom flask fit with a stir bar was capped with a septum and flushed with dry nitrogen gas. To the prepared flask was transferred 40 mL of $CHCl_3$ via cannula. Phenylacetaldehyde (2.23 mL, 20 mmol) was added followed by 1.1 equiv of 1,3-propandedithiol (2.4 mL, 22 mmol), and the reaction solution was allowed to equilibrate for 5 min. To the reaction solution was added 1.1 equiv of $BF_3{\cdot}OEt_2$ (2.7 mL 22 mmol) dropwise over the course of 20 min. The reaction was allowed to stir overnight at room temperature. Upon complete consumption of starting materials (TLC), the reaction was quenched with 2 M NaOH (aq), which was allowed to stir for 10 min before transferring to a separatory funnel. The organic layer was partitioned off and washed sequentially with 2 M NaOH (aq), H_2O, and brine. The chloroform solution was dried over $MgSO_4$ and concentrated by rotary evaporation. The crude product was purified by flash column chromatography (10% EtOAc/Hexane) to yield 2-benzyl-1,3-dithiane **5** (3.65 g, 87%) as a colorless oil that crystallized upon standing (mp 33–35 °C). Spectral data are in agreement with the literature.[54] ^1H NMR (400 MHz, $CDCl_3$): δ 7.38–7.32 (m, 2H), 7.32–7.26 (m, 3H), 4.29 (t, J = 7.2 Hz, 1H), 3.07 (d, J = 7.2 Hz, 2H), 2.94–2.80 (m, 4H), 2.18–2.07 (m, 1H), 1.92–1.82 (m, 1H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 137.4, 129.3, 128.4, 127.0, 48.7, 41.8, 30.6, 25.8.

General Procedure for the Synthesis of Title Compounds. In a glovebox, three stock solutions were prepared in 8 mL vials. Solution 1: 1.0 M solution of 2-benzyl-1,3-dithiane **5** in CPME. Solution 2: $Pd(OAc)_2$ (0.025 M; 0.012 g in 2.2 mL CPME), and Xantphos (0.025 M; 0.0313 g in 2.2 mL CPME). Solution 3: 1.7 M solution of potassium *tert*-butoxide (0.816 g in 4.2 mL CPME). The catalyst solution was allowed to complex for 45 min. To prepare the individual reactions, we charged an 8 mL vial containing a stir bar sequentially

DOI: 10.1021/acs.joc.5b00547
J. Org. Chem. 2015, 80, 4123–4131

with 1.00 mL of the dithiane solution, 1.0 mmol of the appropriate aryl bromide by volume for liquid aryl bromides and by mass for solids, 1.0 mL of the catalyst solution, and finally 2.0 mL of the potassium *tert*-butoxide solution. The vial was capped, removed from the glovebox, and placed on an aluminum heating block set to the indicated temperature where it was allowed to age for 24 h. After being cooled to room temperature, the crude reaction solution was filtered through a plug of silica gel atop a bed of Celite, washing with ethyl acetate until the runnings became colorless. The filtrate was transferred to a separatory funnel, and the organic layer was adjusted to pH 7.2 and then washed sequentially with water and brine. The organic layer was dried over $MgSO_4$ and concentrated by rotary evaporation. Unless otherwise indicated, this workup provides the title compounds as analytically pure samples (>98% purity by GC and ^{1}H NMR).

*(4-Methoxyphenyl)(3-(styrylthio)propyl)sulfane (**6**).* The title compound was prepared using the general procedure with 4-bromoanisole (0.125 mL, 1.0 mmol). Workup of the reaction resulted in a brown oil (0.290 g, 92%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.43 (d, J = 8.4 Hz, 2H), 7.38−7.31 (m, 4H), 7.29−7.23 (m, 1H), 6.89 (d, J = 8.8 Hz, 2H), 6.74 (d, J = 15.6 Hz, 1H), 6.54 (d, J = 15.6 Hz, 1H), 3.80 (s, 3H), 3.01 (t, J = 7.0 Hz, 2H), 2.96 (t, J = 7.0 Hz, 2H), 2.01 (quintet, J = 7.0 Hz, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 159.1, 137.0, 133.4, 128.7, 127.5, 127.0, 126.0, 125.6, 124.8, 114.7, 55.34, 34.5, 31.2, 28.9. EI MS, m/z: 316 (100), 181 (45), 153 (50), 135 (25), 115 (20), 91 (47). HRMS (LIFDI): m/z calculated for $C_{18}H_{20}OS_2$, 316.0956; found, 316.0948; error, 0.8 mDa. IR (neat): 2930, 2834, 1592, 1492, 1239, 1173, 1029, 938, 824, 738, 691 cm^{-1}.

*(2-Methoxyphenyl)(3-(styrylthio)propyl)sulfane (**7**).* The title compound was prepared using the general procedure with 2-bromoanisole (0.125 mL, 1.0 mmol). Workup of the reaction resulted in a yellow oil (0.3062 g, 87%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35−7.26 (m, 5H), 7.27−7.20 (m, 2H), 7.01−6.93 (m, 1H), 6.92−6.87 (m, 1H), 6.70 (d, J = 15.6 Hz, 1H), 6.57 (d, J = 15.6 Hz, 1H), 3.91 (s, 3H), 3.07 (t, J = 7.0 Hz, 2H), 2.97 (t, J = 7.2 Hz, 2H), 2.06 (quintet, J = 7.0 Hz, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 157.6, 137.1, 129.9, 128.7, 127.50, 127.46, 127.0, 125.6, 124.8, 124.0, 121.2, 110.7, 55.8, 31.5, 30.9, 28.7. EI MS, m/z: 316 (100), 181 (60), 153 (35), 135 (20), 115 (15), 91 (40), 65 (10). HRMS (LIFDI): m/z calculated for $C_{18}H_{20}OS_2$, 316.0956; found, 316.0949; error, 0.7 mDa. IR (neat): 3023, 2878, 1594, 1475, 1431, 1270, 1239, 1070, 1023, 936, 715, 690 cm^{-1}.

*Phenyl(4-((3-(styrylthio)propyl)thio)phenyl)methanone (**8**).* The title compound was prepared using the general procedure with 4-bromobenzophenone (0.2609 g, 1.0 mmol). Workup of the reaction resulted in a red brown oil (0.3359g, 86%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.82−7.72 (m, 4H), 7.60 (t, J = 7.2 Hz, 1H), 7.49 (t, J = 7.4 Hz, 2H), 7.39 (d, J = 8.8 Hz, 2H), 7.33−7.26 (m, 4H), 7.23−7.18 (m, 1H), 6.72 (d, J = 15.6 Hz, 1H), 6.55 (d, J = 15.6, 1H), 3.19 (t, J = 7.0 Hz, 2H), 2.98 (t, J = 6.8, 2H), 2.13 (quintet, J = 7.0 Hz, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 195.7, 143.2, 137.8, 136.8, 134.3, 132.3, 130.8, 130.1, 129.9, 128.7, 128.3, 128.0, 127.1, 126.6, 125.6, 124.3, 31.4, 30.7, 28.5. EI MS, m/z: 390 (90), 225 (75), 214 (20), 177 (25), 135 (30), 105 (100), 77 (50). HRMS (LIFDI): m/z calculated for $C_{24}H_{22}OS_2$, 390.1086; found, 390.1112; error, 2.6 mDa. IR (neat): 3054, 2876, 1732, 1650, 1588, 1282, 1272, 936, 921, 730, 696 cm^{-1}.

*Phenyl(3-(styrylthio)propyl)sulfane (**9**).* The title compound was prepared using the general procedure with bromobenzene (0.104 mL, 1.0 mmol). Workup of the reaction resulted in a dark orange oil (0.2807g, 98%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.49−7.42 (m, 2H), 7.42−7.32 (m, 6H), 7.32−7.23 (2H), 6.78 (d, J = 15.6 Hz, 1H), 6.59 (d, J = 15.6 Hz, 1H), 3.14 (t, J = 7.0 Hz, 2H), 3.00 (t, J = 7.0 Hz, 2H), 2.10 (quintet, J = 7.0 Hz, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 137.1, 136.2, 129.4, 129.1, 128.8, 127.6, 127.1, 126.2, 125.7, 124.7, 32.4, 31.3, 28.8. EI MS, m/z: 286 (100), 151 (85), 135 (40), 123 (50), 109 (35, 91 (50), 73 (38). HRMS (LIFDI): m/z calculated for $C_{17}H_{18}S_2$, 286.0850; found, 286.0879; error, 2.9 mDa. IR (neat): 2980, 1733, 1438, 1371, 1238, 1044, 937, 909, 734, 690, 497 cm^{-1}.

*N,N-Dimethyl-4-((3-(styrylthio)propyl)thio)aniline (**10**).* The title compound was prepared using the general procedure with 4-bromoaniline (0.200 g, 1.0 mmol). Workup of the reaction resulted in a dark brown oil (0.279g, 85%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.41 (d, J = 9.2 Hz, 2H), 7.37−7.32 (m, 4H), 7.29−7.23 (m, 1H), 6.76 (d, J = 15.6 Hz, 1H), 6.70 (d, J = 9.2 Hz, 2H), 6.54 (d, J = 15.6, 1H), 3.01−2.94 (m, 10H), 2.01 (quintet, J = 7.0 Hz, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 150.0, 137.1, 134.32, 134.26, 127.4, 126.9, 125.6, 124.9, 120.1, 112.9, 40.5, 35.3, 31.2, 29.0. EI MS, m/z: 329 (90), 176 (10), 152 (100), 134 (15), 115 (10) 91 (45), 77 (10). HRMS (LIFDI): m/z calculated for $C_{19}H_{23}NS_2$, 329.1272; found, 329.1293; error, 2.1 mDa. IR (neat): 3020, 2910, 2800, 1592, 1442, 1350, 1192, 939, 810, 735, 690 cm^{-1}.

*(2-Methylphenyl)(3-(styrylthio)propyl)sulfane (**11**).* The title compound was prepared using the general procedure with 2-bromotoluene (0.120 mL, 1.0 mmol). Workup of the reaction resulted in a yellow oil (0.207 g, 69%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.34−7.26 (5H, m), 7.24−7.09 (4H, m), 6.70 (d, J = 15.6 Hz, 1H), 6.52 (d, J = 15.2 Hz, 1H), 3.08 (t, J = 7.2 Hz, 2H), 2.97 (t, J = 7.0 Hz, 2H), 2.41 (3H, s), 2.06 (quintet, J = 7.1 Hz, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 137.7, 137.0, 135.3, 130.2, 128.1, 127.7, 127.0, 126.5, 125.8, 125.6, 124.5, 31.5, 31.5, 28.6, 20.5. EI MS, m/z: 300 (30), 165 (30), 149 (20), 137 (35), 115 (25), 91 (100), 77 (35), 65 (25), 51 (20). HRMS (LIFDI): m/z calculated for $C_{18}H_{20}S_2$, 300.1006; found, 300.1016; error, 1.0 mDa. IR (neat): 2980, 1734, 1481, 1371, 1237, 1044, 748 cm^{-1}.

*Ethyl 4-((3-(Styrylthio)propyl)thio)benzoate (**12**).* The title compound was prepared using the general procedure with ethyl 4-bromobenzoate (0.163 mL, 1.0 mmol). Workup of the reaction resulted in a dark orange oil (0.2753 g, 77%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.97−7.91 (m, 2H), 7.36−7.26 (m, 6H), 7.24−7.19 (m, 1H), 6.70 (d, J = 15.6 Hz, 1H), 6.53 (d, J = 15.6 Hz, 1H), 4.38 (q, J = 7.1 Hz, 2H), 3.16−3.13 (m, 2H), 2.95 (t, J = 6.8 Hz, 2H), 2.08 (quintet, J = 7.0 Hz, 2H), 1.41 (t, J = 7.0 Hz, 3H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 166.2, 143.2, 136.9, 130.0, 128.7, 128.0, 127.1, 126.8, 125.6, 124.3, 60.9, 31.3, 30.7, 28.4, 28.3, 14.4. EI MS, m/z: 358 (100), 313 (15), 223 (85), 177 (20), 149 (27), 135 (30). HRMS (LIFDI): m/z calculated for $C_{20}H_{22}O_2S_2$, 358.1061; found, 358.1085; error, 2.4 mDa. IR (neat): 3024, 2979, 2877, 1708, 1592, 1270, 1105, 937, 758, 736 cm^{-1}.

*3-((3-(Styrylthio)propyl)thio)thiophene (**13**).* The title compound was prepared using the general procedure with 3-bromothiophene (0.094 mL, 1.0 mmol). Workup of the reaction resulted in a brown oil (0.2095 g, 72%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.31 (m, 5H), 7.21 (m, 2H), 7.10−7.07 (m, 1H), 6.71 (d, J = 15.6 Hz, 1H), 6.52 (d, J = 15.6 Hz, 1H), 3.01 (t, J = 7.2 Hz, 2H), 2.95 (t, J = 7.2 Hz, 2H), 2.02 (q, J = 6.8 Hz, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 137.0, 131.3, 129.8, 128.7, 127.7, 127.0, 126.4, 125.6, 124.6, 124.0, 34.0, 31.2, 28.9. EI MS, m/z: 292 (50), 157 (50), 129 (50), 115 (80), 91 (100), 71 (40), 51 (15). HRMS (LIFDI): m/z calculated for $C_{15}H_{16}S_3$, 292.0414; found, 292.0443; error, 2.9 mDa. IR (neat): 3100, 3019, 2914, 1595, 1493, 1244, 936, 851, 736, 690 cm^{-1}.

*(4-Cyanophenyl)(3-(styrylthio)propyl)sulfane (**14**).* The title compound was prepared using the general procedure with 4-bromobenzonitrile (0.182 g, 1.0 mmol). Workup of the reaction resulted in a brown oil (0.2580 g, 83%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.50−7.46 (m, 2H), 7.34−7.26 (m, 6.8 H, overlapping E/Z isomer), 6.70 (d, J = 15.6 Hz, 1H), 6.53 (d, J = 15.6 Hz, 2H), 3.13 (t, J = 7.2 Hz, 2H), 2.95 (t, J = 6.8 Hz, 2H), 2.08 (quintet, J = 7.0 Hz, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 137.0, 131.4, 129.8, 128.74, 127.7, 127.1, 126.4, 125.6, 124.6, 124.0, 34.0, 31.2, 29.0. EI MS, m/z: 311 (100), 176 (65), 148 (45), 115 (15), 91 (48). HRMS (LIFDI): m/z calculated for $C_{18}H_{17}NS_2$, 311.0802; found, 311.0837; error, 3.5 mDa. IR (neat): 3021, 2876, 2224, 1590, 1233, 1123, 1086, 738 cm^{-1}.

*5-((3-(Styrylthio)propyl)thio)pyrimidine (**15**).* The title compound was prepared using the general procedure with 5-bromopyrimidine (0.159 g, 1.0 mmol). Workup of the reaction resulted in an orange oil (0.2294 g, 80%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.04 (s, 1H), 8.72 (s, 2H), 7.34−7.28 (m, 5H), 6.67 (d, J = 15.2 Hz, 1H), 6.54 (d, J = 15.6 Hz, 1H), 3.14 (t, J = 7.2 Hz, 2H), 2.96 (t, J = 6.8 Hz, 2H), 2.06 (quintet, J = 7.0 Hz, 2H). ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 157.0, 156.2, 136.7, 132.5, 128.7, 128.3, 127.2, 125.6, 123.9, 32.1, 31.1, 28.6. EI MS, m/z: 289 (100), 214 (10), 153 (90), 135 (50), 115 (25), 104

DOI: 10.1021/acs.joc.5b00547
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(11), 91 (68), 73 (23). HRMS (LIFDI): m/z calculated for $C_{15}H_{16}N_2S_2$, 288.0755; found, 288.0772; error, 1.7 mDa. IR (neat): 3023, 2877, 1595, 1538, 1416, 1401, 936, 737, 719, 690, 625 cm^{-1}.

*(4-Chlorophenyl)(3-(styrylthio)propyl)sulfane (**16**).* The title compound was prepared using the general procedure with 4-chlorobromobenzene (0.1970 g, 1.0 mmol). Workup of the reaction resulted in a dark orange oil (0.3016 g, 94%). ^1H NMR (400 MHz, $CDCl_3$): δ 7.43−7.24 (m, 10H, cis isomer included), 6.76 (d, J = 15.6 Hz, 1H), 6.58 (d, J = 15.6 Hz, 1H), 3.09 (t, J = 7.0 Hz, 2H), 2.98 (t, J = 7.0 Hz, 2H), 2.06 (quintet, J = 7.1 Hz, 2H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 136.9, 134.6, 132.1, 130.7, 129.2, 128.7, 127.9, 127.1, 125.6, 124.4, 32.5, 31.2, 28.6. EI MS, m/z: 320 (100), 185 (80), 157 (55), 134 (80), 105 (55), 91 (100), 77 (100), 51 (50). HRMS (LIFDI): m/z calculated for $C_{17}H_{17}ClS_2$, 320.0460; found, 320.0434; error, 2.6 mDa.

*Naphthalen-1-yl(3-(styrylthio)propyl)sulfane (**17**).* The title compound was prepared using the general procedure with 1-bromonapthalene (0.139 mL, 1.0 mmol). Workup of the reaction resulted in a brown oil (0.2934 g, 93%). ^1H NMR (400 MHz, $CDCl_3$): δ 8.56 (d, J = 8.4 Hz, 1H), 7.94 (d, J = 8.0 Hz, 1H), 7.82 (d, J = 8.0 Hz, 1H), 7.71−7.58 (m, 3H), 7.48 (t, J = 7.6 Hz, 1H), 7.46−7.42 (m, 5H), 6.77 (d, J = 15.2 Hz, 1H), 6.59 (d, J = 15.6 Hz, 1H), 3.20 (t, J = 6.8 Hz, 2H), 3.01 (t, J = 7.0 Hz, 1H), 2.10 (quintet, J = 7.0 Hz, 2H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 137.1, 134.1, 133.3, 133.2, 128.77, 128.76, 128.4, 127.7, 127.5, 127.1, 126.6, 126.4, 125.73, 125.68, 125.2, 124.7, 32.97, 31.4, 28.9. EI MS, m/z: 336 (70), 201 (10), 173 (40), 159 (42), 134 (44), 115 (100), 91 (65), 77 (30), 51 (15). HRMS (LIFDI): m/z calculated for $C_{21}H_{20}S_2$, 336.1006; found, 336.1035; error, 2.9 mDa. IR (neat): 3052, 2877, 1595, 1381, 936, 798, 788, 769, 736, 690 cm^{-1}.

*(4-tert-Butylphenyl)(3-(styrylthio)propyl)sulfane (**18**).* The title compound was prepared using the general procedure with 4-*tert*-butyl bromobenzene (0.175 mL, 1.0 mmol). Workup of the reaction resulted in a red orange oil (0.3171 g, 93%). ^1H NMR (400 MHz, $CDCl_3$): δ 7.44−7.35 (m, 8H), 7.32−7.26 (m, 1H), 6.80 (d, J = 15.6 Hz, 1H), 6.61 (d, J = 15.6 Hz, 1H), 3.14 (d, J = 7.0 Hz, 2H), 3.02 (t, J = 7.0 Hz, 2H), 2.11 (quintet, J = 7.0 Hz, 2H), 1.37 (s, 9H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 149.5, 137.1, 132.5, 129.7, 129.6, 128.8, 127.6, 127.0, 126.2, 125.7, 124.8, 34.6, 32.8, 31.5, 31.4, 28.9. EI MS, m/z: 342 (100), 207 (75), 177 (30), 149 (37), 115 (25), 91 (45). HRMS (LIFDI): m/z calculated for $C_{21}H_{26}S_2$, 342.1476; found, 342.1481; error, 0.5 mDa. IR (neat): 3022, 2958, 2855, 1735, 1494, 1239, 1119, 937, 819, 737, 690, 547 cm^{-1}.

*Styryl(3-((4-(trifluoromethyl)phenyl)thio)propyl)sulfane (**19**).* The title compound was prepared using the general procedure with 4-bromobenzotrifluoride (0.140 mL, 1.0 mmol). Workup of the reaction resulted in a dark orange oil (0.2807 g, 98%). ^1H NMR (400 MHz, $CDCl_3$): δ 7.63−7.50 (m, 2H), 7.47−7.31 (m, 6H), 7.31−7.24 (m, 1H), 6.77 (d, J = 15.6 Hz, 1H), 6.61 (d, J = 15.6 Hz, 1H), 3.19 (t, J = 7.0 Hz, 2H), 2.99 (t, J = 7.0 Hz, 2H), 2.12 (quintet, J = 7.0 Hz, 2 H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 141.96, 141.95, 136.9, 128.8, 128.0 127.5, 127.2, 125.8, 125.8, 125.7, 124.4, 31.3, 31.0, 28.4. EI MS, m/z: 354 (100), 219 (75), 191 (50), 135 (40), 91 (50), 73 (30). HRMS (LIFDI): m/z calculated for $C_{18}H_{17}F_3S_2$, 354.0724; found, 354.0712; error, 1.2 mDa. IR (neat): 3022, 2919, 1605, 1323, 1117, 1093, 1062, 1012, 822, 736, 690 cm^{-1}.

*(4-Fluorophenyl)(3-(styrylthio)propyl)sulfane (**20**).* The title compound was prepared using the general procedure with 4-fluorobromobenzene (0.110 mL, 1.0 mmol). Workup of the reaction resulted in a brown oil (0.2549 g, 84%). ^1H NMR (400 MHz, $CDCl_3$): δ 7.41−7.35 (m, 2H), 7.35−7.26 (m, 4H), 7.25−7.19 (m, 1H), 7.00 (t, J = 8.4 Hz, 2H), 6.68 (d, J = 15.6 Hz, 1H), 6.51 (d, J = 15.6 Hz, 1H), 3.03 (t, J = 7.2 Hz, 2H), 2.94 (t, J = 7.0 Hz, 2H), 2.00 (quintet, J = 7.0 Hz, 2H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 161.9 (d, $^1J_{C-F}$ = 245 Hz), 136.9, 132.5 (d, $^3J_{C-F}$ = 7.9 Hz), 128.7, 127.8, 127.1, 125.6, 124.5, 116.1 (d, $^2J_{C-F}$ = 21.7 Hz), 33.7, 31.2, 28.7. EI MS, m/z: 304 (100), 169 (75), 141 (50), 115 (10), 91 (45), 73 (12). HRMS (LIFDI): m/z calculated for $C_{17}H_{17}FS_2$, 304.0756; found, 304.0746; error, 1.0 mDa. IR (neat): 2980, 1733, 1489, 1371, 1237, 1044, 938, 823, 736, 691 cm^{-1}.

*3-((3-(Styrylthio)propyl)thio)pyridine (**21**).* The title compound was prepared using the general procedure with 3-bromopyridine (0.096 mL, 1.0 mmol). Workup of the reaction resulted in a dark orange oil (0.2586 g, 90%). ^1H NMR (400 MHz, $CDCl_3$): δ 8.60 (s, 1H), 8.41 (s, 1H), 6.66 (d, J = 8.0 Hz, 1H), 7.32−7.24 (m, 4H), 7.22−7.13 (m, 2H), 6.66 (d, J = 15.6 Hz, 1H), 6.49 (d, J = 15.6 Hz, 1H), 3.06 (t, J = 7.0 Hz, 2H), 2.90 (t, J = 7.0 Hz, 2H), 1.99 (p, J = 7.0 Hz, 2H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 150.4, 147.3, 137.0, 136.8, 128.7, 127.9, 127.1, 125.6, 124.3, 123.7, 32.3, 31.2, 28.6. EI MS, m/z: 287 (80), 213 (15), 152 (100), 135 (45), 124 (47), 111 (15), 91 (83), 78 (10), 51 (8). HRMS (LIFDI): m/z calculated for $C_{16}H_{17}NS_2$, 287.0802; found, 287.0787; error, 1.5 mDa. IR (neat): 2980, 2927, 1732, 1371, 1238, 1044, 938, 794, 737, 691 cm^{-1}

*General Procedure (B) for the Synthesis of Substituted 2-benzyl-1,3-dithianes (**27**−**29**).* A solution of 1,3-dithiane (0.66 g, 5.5 mmol) in dry THF was cooled in a dry ice/acetone bath. To this cooled solution was added *n*-BuLi (2.8 mL, 2.5 M in hexanes, 5.5 mmol) dropwise over 20 min, and the solution was then allowed to stir for an hour. After complete addition, the reaction solution was removed from the cooling bath and then allowed to warm to ∼0 °C. The reaction flask was placed back into the cooling bath before adding 5.0 mmol of the appropriate benzyl bromide or chloride dropwise over 30 min. The reaction was allowed to stir for 10 min, removed from the cooling bath, and allowed to stir at room temperature overnight. The reaction was subjected to a standard aqueous:organic partition by washing the organic layer sequentially with sodium bicarbonate, water, then brine before drying the organic layer over magnesium sulfate. After the desiccant was filtered away, the solution was concentrated in vacuo, and the crude product was purified by either flash chromatography or recrystallization.

*2-(2-Fluorophenyl)methyl-1,3-dithiane (**27**).* Reagent was prepared using general procedure B with 2-fluorobenzyl bromide (0.603 mL, 5.0 mmol). Workup resulted in a solid that was recrystallized in ethanol (0.616 g, 54%). ^1H NMR (400 MHz, $CDCl_3$): δ 7.29−7.24 (m, 2H), 7.12−7.04 (m, 2H), 4.32 (t, 1H), 3.12 (d, J = 7.6 Hz, 2H), 2.88−2.85 (m, 4H), 2.16−2.10 (m, 1H), 1.94−1.88 (m, 1H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): 161.2 (d, $^1J_{C-F}$ = 244 Hz), 131.7 (d, $^1J_{C-F}$ = 4.4 Hz), 128.8 (d, $^1J_{C-F}$ = 8.2 Hz), 124.4 (d, $^1J_{C-F}$ = 15.5 Hz), 123.8 (d, $^1J_{C-F}$ = 3.2 Hz), 115.4 (d, $^1J_{C-F}$ = 21.8 Hz), 47.1, 36.1, 30.2, 25.7. EI MS, m/z: 228 (5), 119 (100), 109 (20). HRMS (LIFDI): m/z calculated for $C_{11}H_{13}FS_2$, 228.0443; found, 228.0417; error, 2.6 mDa.

*2-(4-Fluorophenyl)methyl-1,3-dithiane (**28**).* Reagent was prepared using general procedure B with 4-fluorobenzyl bromide (0.68 mL, 5.0 mmol). Workup and column chromatography with 5% EtOAc/heptane resulted in a light yellow oil (0.833g, 73%). Spectral data are in agreement with the literature.[55] ^1H NMR (400 MHz, $CDCl_3$): δ 7.24−7.18 (m, 2H), 7.03−6.96 (m, 2H), 4.22 (t, J = 7.2 Hz, 1H), 3.01 (d, J = 7.6 Hz, 2H), 2.86−2.77 (m, 4H), 2.14−2.02 (m, 1H), 1.92−1.79 (m, 1H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 161.9 (d, $^1J_{C-F}$ = 243.6 Hz), 131.1 (d, $^4J_{C-F}$ = 3.3 Hz), 130.8 (d, $^3J_{C-F}$ = 8.1 Hz), 115.1 (d, $^2J_{C-F}$ = 21.3 Hz), 48.6, 41.0, 30.5, 25.7. EI MS, m/z: 228 (5), 119 (100), 109 (20).

*2-(4-Methoxyphenyl)methyl-1,3-dithiane (**29**).* Reagent was prepared using general procedure B with 4-methoxybenzyl chloride (0.68 mL, 5.0 mmol). Neutral workup resulted in a solid that was recrystallized in ethanol (0.6481 g, 54%). Spectral data are in agreement with the literature.[56] ^1H NMR (400 MHz, $CDCl_3$): δ 7.19 (d, J = 8.4 Hz, 2H), 6.87 (d, J = 8.4 Hz, 2H), 4.23 (t, J = 7.2 Hz, 1H), 3.81 (s, 3H), 2.99 (d, J = 7.2 Hz, 2H), 2.87−2.84 (m, 4H), 2.14 (m, 1H), 1.89 (m, 1H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 158.6, 130.2, 129.4, 113.75, 55.2, 49.01, 40.94, 30.56, 25.82. EI MS, m/z: 240 (10), 119 (100).

*(E/Z)-(2-Fluorostyryl)(3-((4-methoxyphenyl)thio)propyl)sulfane (**30**).* The title compound was prepared using the general procedure with 2-(2-fluorobenzyl)-1,3-dithiane (0.2058 g, 0.9 mmol) and 4-bromoanisole (0.113 mL, 0.9 mmol). Neutral workup resulted in a dark orange oil (0.297 g, 89%). ^1H NMR (400 MHz, $CDCl_3$): δ 7.43−7.37 (m, 2H), 7.37−7.31 (m, 1H), 7.21−7.14 (m, 1H), 7.12−7.01 (m, 2H), 6.91−6.79 (m, 3H), 6.60 (d, J = 15.6 Hz, 1H), 3.78 (s, 3H), 2.99 (t, J = 6.2 Hz, 2H), 2.96 (t, J = 6.2 Hz, 2H), 1.99 (quintet, J = 7.0 Hz,

DOI: 10.1021/acs.joc.5b00547
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2H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 160.74, 159.07, 158.26, 133.45, 133.40, 132.26, 128.02, 127.97, 127.94, 127.91, 127.73, 126.82, 126.78, 125.90, 124.91, 124.78, 124.24, 124.21, 119.37, 119.34, 115.88, 115.78, 116.66, 114.70, 114.62, 55.31, 34.46, 31.00, 28.78 (complexities due to carbon−fluorine splitting). EI MS, m/z: 334 (100), 195 (40), 181 (30), 167 (35), 153 (48), 139 (45), 109 (50). HRMS (LIFDI): m/z calculated for $C_{18}H_{19}FOS_2$, 334.0861; found, 334.0887; error, 2.6 mDa. IR (neat): 3033, 2878, 1592, 1491, 1481, 1283, 1241, 1224, 1029, 939, 822, 749 cm^{-1}.

(E/Z)-3-((3-((2-Fluorostyryl)thio)propyl)thio)pyridine (**31**). The title compound was prepared using the general procedure from 2-(2-fluorobenzyl)-1,3-dithiane (0.2285 g, 1.0 mmol) with 3-bromopyridine (0.096 mL, 1.0 mmol), 1.0 mL of catalyst stock solution (0.025 mmol), and potassium *tert*-butoxide (2.0 mL stock solution, 3.0 mmol). Neutral workup resulted in a brown oil (0.281 g, 81%). ^1H NMR (400 MHz, $CDCl_3$): δ 8.63−8.56 (m, 1H), 8.46−8.38 (m, 1H), 7.69−7.63 (m, 1H), 7.26−7.16 (m, 3H), 7.08−6.93 (m, 2H), 6.57 (d, J = 15.6 Hz, 1H), 6.46 (d, J = 16.6 Hz), 3.08 (t, J = 7.0 Hz, 2H), 2.94 (t, J = 7.0 Hz, 2H), 2.01 (quintet, J = 7.0 Hz, 2H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 163.1, 160.7, 150.3, 147.3, 137.0, 133.2, 133.1, 133.0, 130.4, 130.2, 127.1, 127.0, 126.8, 124.0, 123.9, 123.7, 115.6, 155.4, 115.3, 115.0, 34.0, 32.3, 32.0, 31.2, 31.0, 29.2, 28.6. EI MS, m/z: 305 (50), 231 (35), 152 (100), 124 (38), 109 (75). HRMS (LIFDI): m/z calculated for $C_{16}H_{16}FNS_2$, 305.0708; found, 305.0729; error, 2.1 mDa. IR (neat): 3032, 1595, 1481, 1223, 1196, 939, 749, 704, 617, 492, 460 cm^{-1}.

(E)-(4-Fluorostyryl)(3-((4-methoxyphenyl)thio)propyl)sulfane (**32**). The title compound was prepared using the general procedure from 2-(4-fluorobenzyl)-1,3-dithiane (0.188 mL, 1 mmol) with 4-bromoanisole (0.125 mL, 1.0 mmol). Neutral workup resulted in a brown oil (0.301, 90%). ^1H NMR (400 MHz, $CDCl_3$): δ 7.39 (d, J = 8.8 Hz, 2H), 7.24 (dd, J = 8.8 Hz, 2H), 7.00 (t, J = 8.6 Hz, 2H), 6.86 (d, J = 8.8 Hz, 2H), 6.61 (d, J = 15.6 Hz, 1H), 6.46 (d, J = 15.6 Hz, 1H), 3.78 (s, 3H), 2.98 (t, J = 6.8 Hz, 2H), 2.92 (t, J = 7.0, 2H), 1.98 (quintet, J = 7.2 Hz, 2H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 163.1, 160.7, 159.1, 133.33, 133.28, 127.07, 126.99, 126.39, 125.95, 124.48, 124.46, 115.65, 115.43, 114.71, 55.29, 34.41, 31.20, 28.87 (unable to assign signals due to complexities from carbon−fluorine coupling). EI MS, m/z: 334 (75), 195 (30), 181 (34), 167 (32), 153 (90), 139 (85), 109 (100). HRMS (LIFDI): m/z calculated for $C_{18}H_{19}FOS_2$, 334.0861; found, 334.0877; error, 1.6 mDa. IR (neat): 2929, 2834, 1506, 1492, 1240, 1226, 1030, 823, 730, 525, 512 cm^{-1}.

(E/Z)-3-((3-((4-Fluorostyryl)thio)propyl)thio)pyridine (**33**). The title compound was prepared using the general procedure from 2-(4-fluorobenzyl)-1,3-dithiane (0.188 mL, 1.0 mmol) with 3-bromopyridine (0.096 mL, 1.0 mmol). Workup resulted in a brown oil (0.254 g, 83%). ^1H NMR (400 MHz, $CDCl_3$): δ 8.60−8.56 (m, 1H), 8.42−8.38 (m, 1H), 7.66−7.60 (m, 1H), 7.25−7.13 (m, 4H), 7.00−6.921 (m, 2H), 6.56 (d, J = 15.6 Hz, 1H), 6.44 (d, J = 15.6 Hz, 1H), 3.06 (t, J = 7.0 Hz, 2H), 2.90 (t, J = 7.0 Hz, 2H), 2.00−1.97 (m, 2H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 160.7, 158.2, 150.4, 147.3, 137.0, 133.2, 130.4, 128.1, 128.0, 127.52, 127.45, 126.80, 126.76, 124.7, 124.6, 124.20, 124.17, 123.7, 119.74, 119.71, 115.8, 115.6, 32.3, 30.9, 28.5 (unable to assign signals due to complexities from carbon−fluorine coupling). EI MS, m/z: 305 (65), 231 (25), 152 (100), 124 (40), 109 (80). HRMS (LIFDI): m/z calculated for $C_{16}H_{16}FNS_2$, 305.0708; found, 305.0696; error, 1.2 mDa. IR (neat): 2959, 2922, 1505, 1224, 1107, 1093, 1017, 837, 788, 704, 526, 512 cm^{-1}.

(E/Z)-(4-Methoxyphenyl)(3-((4-methoxystyryl)thio)propyl)sulfane (**34**). The title compound was prepared using the general procedure with 2-(4-methoxybenzyl)-1,3-dithiane (0.2402 g, 1.0 mmol), 4-bromoanisole (0.125 mL, 1.0 mmol), 1.0 mL of catalyst stock solution (0.025 mmol), and potassium *tert*-butoxide (2.0 mL stock solution, 3.0 mmol). Workup resulted in a brown oil (0.281 g, 81%). ^1H NMR (400 MHz, $CDCl_3$): δ 7.40 (d, J = 8.8 Hz, 2H), 7.24 (d, J = 8.8 Hz, 2H), 6.92−6.81 (m, 4H), 6.53 (d, J = 4.4 Hz, 2H), 3.81 (s, 3H), 3.78 (s, 3H), 2.99 (t, J = 7.0 Hz, 2H), 2.91 (t, J = 7.0 Hz, 2H), 1.98 (quintet, J = 7.0 Hz, 2H). $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 159.0, 158.9, 133.3, 130.0, 128.0, 126.8, 126.1, 121.9, 114.7, 114.2, 55.3, 34.4, 31.4, 29.0 (unable to assign signals due to complexities from carbon−fluorine coupling). EI MS, m/z: 346 (100), 181 (65), 153 (90), 139 (85), 121 (80), 77 (40). HRMS (LIFDI): m/z calculated for $C_{19}H_{22}O_2S_2$, 346.1061; found, 346.1052; error, 0.9 mDa. IR (neat): 3025, 2879, 2224, 1591, 1506, 1492, 1240, 1226, 1030, 823 cm^{-1}.

■ ASSOCIATED CONTENT

Supporting Information

^1H and ^{13}C NMR of all title compounds. This material is free of charge via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

Bryn Mawr College and the Isabel H. Benham Fund for Faculty Research are acknowledged for funding support. N.A. acknowledges the Bryn Mawr College Dean's Fellowship for financial support. The authors acknowledge the National Science Foundation for a Major Research Instrumentation award (CHE-0958996), which paid for the NMR spectrometer used in these studies. The authors acknowledge Mr. Jesse McAtee (University of Delaware) for HRMS data.

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