Studies on the Alkylation of 3-Methyl-3-buten-1-ol Dianion: An Efficient Synthesis of 3-Methylene-1-alkanols Including a San Jose Scale Sex Pheromone

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The San Jose scale, *Quadraspidiotus perniciosus*, is a serious agricultural pest that infests fruit trees worldwide.[1] It has been established that ester **1**, one of the major components of the female-produced sex pheromone of this insect, may be effectively used to monitor male populations as part of an integrated pest management program.[2] Pheromone **1** has been previously prepared by Anderson,[3] Weiler,[4] Weedon,[5] and others.[6−8] Each of these syntheses has its merits but is limited by length (e.g., six steps for the Weiler synthesis) or difficult chemistry (e.g., copper-catalyzed carbocupration of an alkyne which proceeds in low yield in the Anderson synthesis). Thus, there still remains a need to develop a short, practical synthesis of this important compound. A simple retrosynthetic analysis of **1** (Scheme 1) suggests that an expedient route might be via alkylation of 3-methyl-3-buten-1-ol (**2**) with a derivative of itself. Thus, 5-carbon alcohol **2** would provide all 10 carbons of the pheromone backbone, and in principle, an irresistibly simple synthesis of **1** could be achieved in three easy steps consisting of tosylation, alkylation, and esterification. We now report our findings on the long journey toward a short synthesis.

The generation of the dilithio derivative of **2** and its alkylation with allylic halides has been known since 1974;[9,10] reactions with aldehydes are also known.[11] However, there are no reports of attempts to generalize this chemistry to other alkylating agents.[12] Such a generalization would allow rapid access to various compounds that are 3-methylene-1-alkanols or derivatives thereof, such as pheromone **1** and the natural products and synthetic intermediates shown in Figure 1. Routes

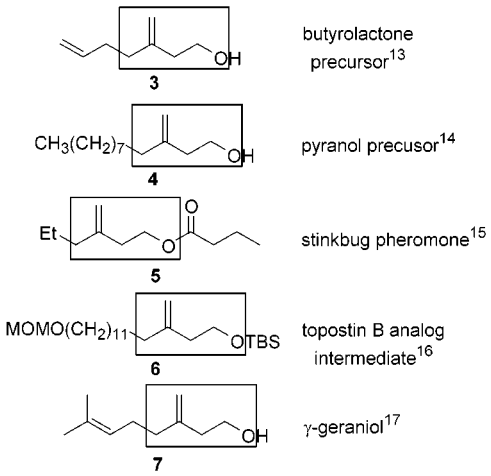
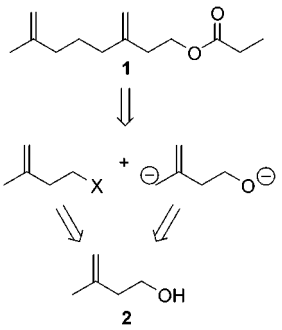


Figure 1. Some compounds possessing the 3-methylene-1-alkanol unit.

Scheme 1



to each of the compounds shown in Figure 1 are known, but the general proposed alkylation route would be much faster. Also, it has been recently shown that alkylation of **2** with allyl bromide using the conditions originally described (*n*-BuLi, TMEDA) is a very poor reaction, and alternative metalation conditions (KH, *n*-BuLi) were needed to achieve synthetically useful (28−33%) yields of the desired allylated product **3**.[13] Thus, there was clearly a need to further examine the alkylation of **2**.

The tosylate of **2** was used in initial alkylation studies since it is easily prepared and handled and would provide a fast entry to **1**. Lithiation of **2** under the reported conditions[9] (*n*-BuLi, TMEDA, rt, overnight) followed by addition of tosylate **8** provided the desired alcohol **9** but in only modest (20−40%) yields. Numerous experiments in which stoichiometry, concentration, temperature and reaction times were varied did not give meaningfully different results. Moreover, varying amounts of side-products were observed in each experiment. The most significant of these side-products was isolated and identi-

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(6) CAN 120:217021: Zhang, H.; Chen, J.; Xu, Z. *Youji Huaxue* **1993**, *13*, 504−507.
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(10) Poppe, L.; Novak, L.; Szantay, C. *Synth. Commun.* **1987**, *17*, 173−179.
(11) Cardillo, G.; Contento, M.; Sandri, S.; Panunzio, M. *J. Chem. Soc., Perkin Trans. 1* **1979**, 1729−1733.
(12) During the preparation of this manuscript, a SciFinder structure search for preparations of **1** uncovered a French patent in which the dianion of **2** was treated with tosylate **8** as the key step in a synthesis of **1**, which is apparently also a body lice pheromone: CAN100: 6887 Szantay, C.; Novak, L.; Kis-Tamas, A.; Majoros, B.; Ujvary, I.; Jurak, F. Fr. Demande 1983, FR 2518535 A1 19830624. In our hands, the chemistry described therein was inefficient with variable amounts of sulfonate **10** formed (see text).
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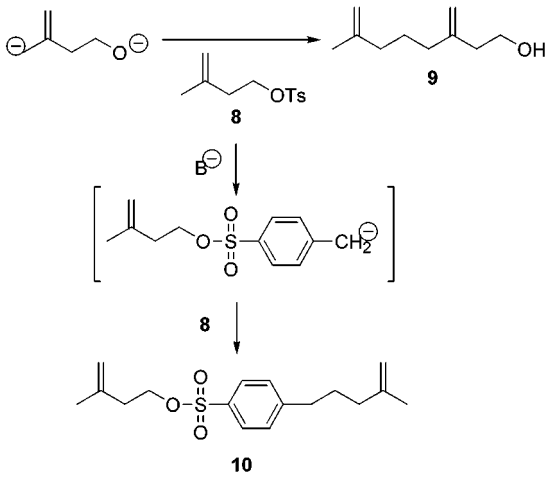
Scheme 2



fied spectroscopically as sulfonate **10**. Compound **10** is likely formed by deprotonation of **8** by the highly basic dianion[18] followed by alkylation with another molecule of **8** (Scheme 2). Thus, it seemed that tosylate **8** would not be the best choice for alkylations and another sulfonate was chosen.

Benzenesulfonate **11**, which should be similar in reactivity to **8** but without relatively acidic benzylic protons, could also be used to alkylate the dianion of **2**. Unfortunately, **11** gave similar mediocre yields of **9** and variable amounts (5−15%) of another unexpected product. This side product was identified spectroscopically as the disubstituted benzene **12**. It is not immediately obvious how **12** is formed but it might arise from an addition−elimination sequence (Scheme 3). Interestingly, Weiler had observed that in alkylations of β-keto ester dianions with derivatives of **2**, highest yields were obtained with halides (Br and I) as opposed to sulfonates (OTs, O_3SPh, OMs) but did not report any side reactions.[4] In light of our results and Weiler's study, we decided to examine the alkylation of the dianion of **2** with a simple primary halide.

A study of alkylations using *n*-octyl bromide revealed that the solvent used in the metalation step as well as the alkylation step has a significant effect on the yield (Table 1). Thus, when the metalation and alkylation were carried out in hexanes, as originally described by Cardillo for allylic halides,[9] the yield of alcohol **2** was only 63% (Table 1, entry 1). When ether or THF was added with the alkyl halide in order to promote alkylation, yields increased somewhat (Table 1, entries 2 and 3). However, the best results by far were obtained using ether as solvent in both the metalation and alkylation steps (Table 1, entry 4). It is also pertinent to note that the yields achieved were reproducible only when mechanical stirring was used; the reaction mixtures were thick slurries (pastes when hexanes were used as solvent) that resisted

Scheme 3

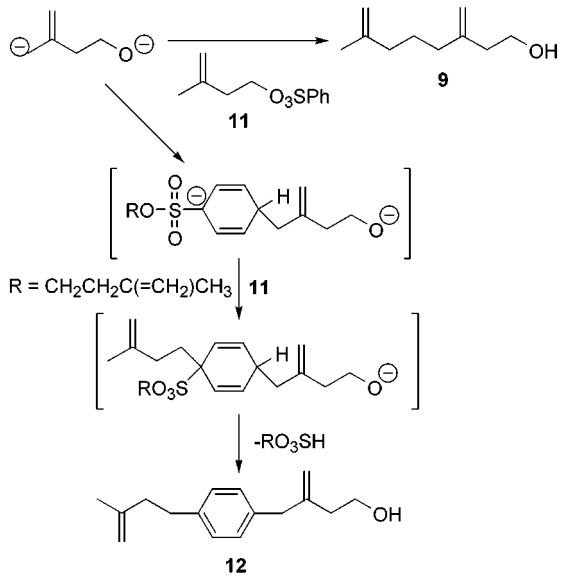
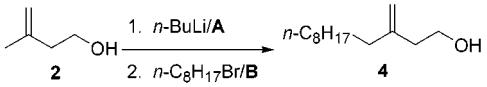


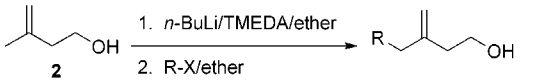
Table 1. Effect of Solvents on the Metalation/Alkylation of 2



entry	metalation solvent (A)	alkylation solvent (B)	yield of **4**[a] (%)
1	hexanes	hexanes	63
2	hexanes	ether	78
3	hexanes	THF	74
4	ether	ether	94

[a] Isolated yields of purified (flash chromatography) products.

Table 2. Alkylation of 2 with Alkyl Halides



3: R = CH_2=$CHCH_2$ **9**: R = $CH_3C(=CH_2)CH_2CH_2$
4: R = n-C_8H_{17} **13**: R = CH_3CH_2
7: R = $(CH_3)_2C$=$CHCH_2$ **14**: R = $MOMO(CH_2)_{11}$

entry	electrophile	product	% yield[a]
1	CH_2=$CHCH_2Br$	**3**	49[b]
2	*n*-$C_8H_{17}Br$	**4**	94
3	$(CH_3)_2C$=$CHCH_2Br$	**7**	84
4	$CH_3C(=CH_2)CH_2CH_2I$ (**15**)	**9**	52
5	CH_3CH_2Br	**13**	51[b,c]
6	$MOMO(CH_2)_{11}Br$ (**16**)	**14**	77

[a] Isolated yields of purified products. [b] Modest isolated yield reflects volatility of product. [c] Yield based on isolated yield of butyrate **5**.

mixing and gave variable (and usually lower) yields with magnetic stirring even on small scales. Time and temperature were also important factors in that it was necessary to allow the metalation to proceed at room temperature for 6 h for complete formation of the dianion while the alkylation was best achieved by cooling the reaction mixture to −78 °C and allowing it to warm to room temperature.

Metalation/alkylation of **2** was carried out with a variety of alkyl halides under our optimized conditions (Table 2). Simple primary bromides (Table 2 entries 2, 5, and 6) gave reactions that were very clean by GC/MS with no byproducts detected. With ethyl bromide, the

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(18) Deprotonation of tosylates by strong bases has been noted previously: (a)Bumgardner, C. L.; Lever, J. R.; Purrington, S. T. *J. Org. Chem.* **1980**, *45*, 748−749. (b)Argüello, J. E.; Peñéñory, A. B.; Rossi, R. A. *J. Org. Chem.* **1999**, *64*, 6115−6118.

resulting alcohol was quite volatile and resisted isolation in good yields; nonetheless, the crude alcohol could be directly treated with butyryl chloride to provide ester **5** in 51% overall yield from alcohol **2**. This route to **5** is much better than the only other published route, which uses an ene reaction to produce **13** as a mixture of isomers.[15] Similarly, use of a MOM-protected ω-bromo alcohol gave compound **14**, which was readily (TBSCl, imidazole, DMF, 94%) converted to compound **6**, a compound previously prepared by a much more lengthy route (six steps, 39% overall yield compared to three steps, 68% overall yield using the present procedure).[16] We also observe a much higher yield of **3** compared to reactions carried out in hexanes (28−33%).[13]

To prepare alcohol **9**, the alcohol required for preparation of pheromone **1**, a homoallylic halide was required as the coupling partner (as we had already shown that sulfonates **8** and **11** give side reactions). Iodide **15** was chosen as the corresponding bromide is too volatile to isolate easily in high yield.[4b] Treatment of **2** with $Ph_3P{\cdot}I_2$[19] provided iodide **15** in 84% yield; alternatively, tosylate **8** could be treated with NaI in acetone to prepare **15** more conveniently and economically on larger scales.[4b] Treatment of the dianion of **2** with **15** proceeded smoothly to give **9** in reasonable yield. It is likely that competing E_2 elimination (to form isoprene) is responsible for the modest yield as all of iodide **15** is consumed in the reaction and an isomeric alcohol **7**, prepared using an allylic halide, can be isolated in much higher yield (suggesting that volatility is not an issue here; compare Table 2, entries 3 and 4). Attempts to suppress elimination by formation of organocopper reagents[20] met with limited success: treatment of the dianion with 1 equiv of CuCN or CuI gave reagents that were essentially unreactive toward iodide **15** while use of 0.5 equiv of CuI (presumably to form a Gilman reagent) gave a reasonable (58%) yield of **9** but with other side products that made purification difficult. Thus direct alkylation of the dilithium salt seems to be the method of choice. Alcohol **9** was readily acylated (propionic anhydride, pyridine, 98%) to complete a short, simple synthesis of pheromone **1** (three steps, 43% overall yield from **2**).

In summary, metalation of alcohol **2** (*n*-BuLi, TMEDA, ether) followed by treatment of the resulting dianion with alkyl halides is a general route to 3-methylene-1-alkanols. Sulfonates may be used but give competing side-reactions. This chemistry could be used advantageously for the preparation of compounds such as the San Jose scale sex pheromone **1**.

Experimental Section

All reactions were carried out under argon using flame-dried glassware. NMR data were recorded on 200 or 300 MHz instruments. Ether was distilled from Na/benzophenone while hexanes and TMEDA were distilled from CaH_2. *n*-BuLi was titrated using *N*-benzylbenzamide.[21] Tosylate **8** and benzenesulfonate **11** (both quantitative) were prepared as described by Weiler;[4b] iodide **15** was also prepared by Weiler's method (60% yield in two steps from **2**) or by the method noted below. MOM ether **16** was prepared by standard methods[16] from 11-bromo-1-undecanol (Aldrich or from 1,11-undecanediol[22]).

General Procedure for Metalation and Alkylation of 2. Method A. A three-necked flask equipped with a mechanical stirrer was charged with TMEDA (4 mL, 26 mmol) and Et_2O (15 mL). The solution was cooled to 0 °C, *n*-BuLi (1.56 M in hexanes, 13 mL, 20 mmol) was added, and the resulting solution was stirred at room temperature for 1 h. The solution was then cooled (0 °C), and alcohol **2** (1.0 mL, 10 mmol) was added slowly. The resulting solution was stirred at room temperature for 6 h to generate the desired dianion as a heterogeneous brown suspension. This slurry was cooled to −78 °C and the appropriate electrophile (5 mmol) in ether (3 mL) was added slowly. The reaction was then allowed to warm to room temperature slowly overnight and stirred at room temperature for 3 h (halides) or 6 h (sulfonates). The reaction was quenched with 20 mL of sat. NH_4Cl and the layers were separated. The aqueous layer was extracted with ether (3 × 30 mL), and the organic layers were combined, dried ($MgSO_4$), and concentrated in vacuo to give the crude product. The product was purified by column chromatography (10−20% ethyl acetate/hexanes)

Method B. This method was used with volatile halides and is the same as method A except that a slight excess of *n*-BuLi (14 mL of 1.56 M solution in hexanes, 22 mmol) was used and 12 mmol of electrophile was added.

7-Methyl-3-methylene-7-octen-1-yl Propanoate (1). Alcohol **9** (3.08 g, 20 mmol) was treated with propionic anhydride (5.2 g, 40 mmol) in pyridine (10 mL) at room temperature. The mixture was stirred at ambient temperature for 2 h and then poured into ice cold 1 M HCl. Standard extractive workup with ether provided pheromone **1** (4.13 g, 98%) as a colorless oil. ^{1}H NMR ($CDCl_3$, 300 MHz) δ 4.82 (br s, 1H), 4.78 (br s, 1H), 4.71 (br s, 1H), 4.68 (br s, 1H), 4.18 (t, J = 7.0 Hz, 2H), 2.34 (m, 4H), 2.03 (m, 4H), 1.72 (s, 3H), 1.56 (m, 2H), 1.13 (t, J = 7.5 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.8, 145.1, 145.0, 110.9, 109.8, 62.4, 37.1, 35.4, 34.8, 27.2, 25.3, 22.0, 8.8; MS(EI) *m/z* 181 (M^+ − 29, 0.1), 136 (12), 121 (28), 93 (43), 57 (100).

3-Methylene-6-hepten-1-ol (3). Method B was used with allyl bromide (1.2 mL, 13.8 mmol). Care was taken to keep the rotovap bath below 25 °C to minimize loss of the volatile product. Purification by flash chromatography (10−20% ethyl acetate/hexanes) afforded 0.62 g (49%) of **3** as a colorless oil whose ^{1}H NMR spectrum matched literature[13] data: ^{1}H NMR ($CDCl_3$, 300 MHz) δ 5.78 (ddt, J = 17.1, 10.3, 6.1 Hz, 1H), 5.01 (ddt, J = 17.1, 1.6, 1.6 Hz, 1H), 4.95 (br d, J = 10.3 Hz, 1H), 4.86 (br s, 1H), 4.83 (br s, 1H), 3.69 (t, J = 6.3 Hz, 2H), 2.28 (br t, J = 6.3 Hz, 2H), 2.15 (m, 4H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 145.3, 138.1, 114.8, 111.9, 60.3, 39.2, 35.0, 31.9; MS(EI) *m/z* 126 (M^+, 0.1), 108 (6), 93 (81), 79 (100).

3-Methylene-1-dodecanol (4).[14] This compound was prepared under a number of different reaction conditions in the yields shown in Table 1. Method A was followed except that hexanes (15 mL) was sometimes used as the metalation solvent and 1-bromooctane was added as a solution in hexanes (3 mL, entry 1), ether (10 mL, entry 2) or THF (10 mL, entry 3). Where ether was used as the metalation solvent, 0.97 g (94%) of **4** was isolated as a colorless oil: ^{1}H NMR ($CDCl_3$, 300 MHz) δ 4.84 (br s, 1H), 4.78 (br s, 1H), 3.68 (t, J = 6.3 Hz, 2H), 2.27 (br t, J = 6.3 Hz, 2H), 2.00 (br t, J = 7.5 Hz, 2H), 1.49 (s, 1H), 1.40 (m, 2H), 1.24 (m, 12H), 0.86 (br t, J = 7.2 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 146.3, 111.2, 60.3, 39.0, 35.8, 31.8, 29.52, 29.47, 29.30, 20.27, 27.7, 22.6, 14.0; MS(EI) *m/z* 198 (M^+, 0.6), 180 (4), 81 (97), 68 (100).

3-Methylenehex-1-yl Butanoate (5).[15] Method B was followed using 1.75 g (16 mmol) of ethyl bromide to give alcohol **13**: ^{1}H NMR ($CDCl_3$, 300 MHz) δ 4.79 (br s, 1H), 4.75 (br s, 1H), 3.65 (t, J = 6.5 Hz, 2H), 2.23 (br t, J = 6.5 Hz, 2H), 2.05 (br s, 1H), 1.41 (m, 2H), 0.86 (t, J = 7.4 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 146.0, 111.3, 60.3, 39.0, 37.9, 20.7, 13.7; MS(EI) 114 (M^+, 0.5), 96 (14), 81 (100). The crude alcohol was treated with butyryl chloride (1.33 g, 12.5 mmol) and Et_3N (2 mL) in CH_2Cl_2 to give 0.94 g (51% from **2**) of ester **5** as an oil after flash chromatography (30% CH_2Cl_2 in hexanes): ^{1}H NMR ($CDCl_3$, 300 MHz) δ 4.78 (br s, 1H), 4.74 (br s, 1H), 4.15 (t, J = 7.0 Hz, 2H), 2.30 (t, J = 7.0 Hz, 2H), 2.25 (t, J = 7.5 Hz, 2H), 1.99 (br t, J =

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7.5 Hz, 2H), 1.62 (m, 2H), 1.43 (m, 2H), 0.90 (t, J = 7.4 Hz, 3H), 0.85 (t, J = 7.3 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.6, 145.5, 111.1, 62.6, 38.2, 36.2, 34.9, 20.7, 18.4, 13.7, 13.6; MS-(EI) m/z 141 (M^+ − 43, 0.1), 96 (28), 81 (75), 71 (58), 68 (100).

1-*tert*-Butyldimethylsiloxy-15-methoxymethoxy-3-methylenepentadecane (6). Method A was used with 1.45 g (4.9 mmol) of bromide **16** to provide 1.14 g (77%) of alcohol **14**: ^{1}H NMR ($CDCl_3$, 300 MHz) δ 4.84 (br s, 1H), 4.79 (br s, 1H), 4.60 (s, 2H), 3.68 (t, J = 6.3 Hz, 2H), 3.49 (t, J = 6.6 Hz, 2H), 3.34 (s, 3H), 2.27 (br t, J = 6.3 Hz, 2H), 2.00 (br t, J = 7.4 Hz, 2H), 1.55 (m, 2H), 1.40 (m, 2H), 1.24 (br m, 16H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 146.3, 111.3, 96.3, 67.8, 60.3, 55.0, 39.1, 35.8, 29.7, 29.54, 29.51, 29.44, 29.37, 29.3, 27.7, 26.1; MS(EI) m/z 250 (2), 109 (27), 95 (55), 81 (100). Anal. Calcd for $C_{18}H_{36}O_3$: C, 71.95; H, 12.08. Found: C, 72.04; H, 11.83. This alcohol (0.30 g, 1.0 mmol) was treated with TBSCl (0.17 g, 1.1 mmol) and imidazole (0.18 g, 2.7 mmol) in DMF (0.5 mL) to afford 0.39 g (94%) of **6**:[16] ^{1}H NMR ($CDCl_3$, 300 MHz) δ 4.72 (br s, 1H), 4.69 (br s, 1H), 4.60 (s, 2H), 3.67 (t, J = 7.3 Hz, 2H), 3.49 (t, J = 6.6 Hz, 2H), 3.34 (s, 3H), 2.21 (br t, J = 7.3 hz, 2H), 1.98 (br t, J = 7.5 Hz, 2H), 1.55 (m, 2H), 1.38 (m, 2H), 1.24 (m, 16H), 0.87 (s, 9H), 0.03 (s, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 147.0, 110.2, 96.3, 67.8, 62.5, 55.0, 39.3, 36.5, 29.7, 29.61, 29.58 (2C), 29.5, 29.43, 29.36, 27.7, 26.2, 25.9, 18.3, −5.3; MS(EI) m/z 383 (M^+ − 31, 0.1), 75 (100).

γ-Geraniol (7).[17] Method A was used with 0.75 g (5 mmol) of 1-bromo-3-methyl-2-butene (prenyl bromide) to afford 0.65 g of **7** (84%) as a fragrant oil: ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.05−5.13 (m, 1H), 4.86 (br s, 1H), 4.82 (br s, 1H), 3.69 (t, J = 6.3 Hz, 2H), 2.29 (t, J = 6.3 Hz, 2H). 2.00−2.15 (m, 4H), 1.67 (s, 3H), 1.59 (s, 3H) 1.46 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 145.8, 131.9, 123.8, 111.6, 60.3, 39.2, 35.7, 26.3, 25.6, 17.7; MS(EI) m/z 154 (M^+, 0.8), 136 (9), 93 (59), 69 (100).

7-Methyl-3-methylene-7-octen-1-ol (9).[3] Method A was followed using 1.0 g of iodide **15** to give 0.41 g (52%) of alcohol **9** as a colorless oil after flash chromatography: ^{1}H NMR ($CDCl_3$, 300 MHz) δ 4.86 (br s, 1H), 4.81 (br s, 1H), 4.69 (br s, 1H), 4.66 (br s, 1H), 3.69 (t, J = 6.3 Hz, 2H), 2.29 (t, J = 6.2 Hz, 2H), 2.0 (m, 4H), 1.70 (s, 3H), 1.57 (m, 2H) 1.45 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 145.9, 145.5, 111.5, 109.9, 60.3, 39.0, 37.3, 35.3, 25.5, 22.3; MS(EI) m/z 154 (M^+, 0.8), 136 (9), 93 (59), 69 (100).

3-Methyl-3-buten-1-yl 4-(4-Methyl-4-penten-1-yl)benzenesulfonate (10). Reactions using method A and tosylate **8** provided the desired alcohol **9** along with heretofore unreported sulfonate **10** (5−20% yields), which was isolated by flash chromatography (R_f = 0.5 with 20% ethyl acetate in hexanes): IR (neat) 1651, 1360, 1175, 780 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.75 (br s, 1H), 4.72 (br s, 1H), 4.65 (m, 2H), 4.11 (t, J = 6.8 Hz, 2H), 2.66 (br t, J = 7.7 Hz, 2H), 2.32 (br t, J = 6.8 Hz, 2H), 2.02 (br t, J = 7.4 Hz, 2H), 1.75 (m, 4H), 1.69 (s, 3H), 1.62 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 149.1, 144.8, 140.0, 133.3, 129.1, 127.9, 113.0, 110.4, 68.4, 37.0, 36.6, 35.2, 28.7, 22.2; MS-(EI) m/z 308 (M^+, 0.1), 184 (7), 69 (100). Anal. Calcd for $C_{17}H_{24}O_3S$: C, 66.20; H, 7.84. Found: C, 66.42; H, 7.68.

3-[4-(3-Methyl-3-butenyl)phenyl]methyl-3-buten-1-ol (12). Reactions using method A with benzenesulfonate **11** provided the desired alcohol **9** along with heretofore unreported alcohol **12** (5−15% yields), which was isolated by flash chromatography (R_f = 0.14 with 20% ethyl acetate in hexanes): IR (neat) 3338, 1648, 1511, 1043, 889 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.10 (m, 4H), 4.90 (m, 2H), 4.73 (br s, 1H), 4.70 (br s, 1H), 3.67 (t, J = 6.4 Hz, 2H), 3.33 (s, 2H), 2.71 (m, 2H), 2.26 (m, 4H), 1.76 (s, 3H), 1.59 (br s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 145.5, 145.4, 140.1, 136.5, 128.8, 128.3, 113.6, 110.1, 60.3, 42.4, 39.6, 38.4, 33.8, 22.6; MS(FAB) m/z 231 (M + 1,12), 230 (19), 213 (17), 175 (100), 157 (73). Anal. Calcd for $C_{16}H_{22}O$: C, 83.43; H, 9.63. Found: C, 83.64; H, 9.58.

4-Iodo-2-methyl-1-butene (15).[4b,19] To a solution of Ph_3P (15.72 g, 60 mmol) in CH_2Cl_2 (150 mL) at room temperature were sequentially added imidazole (4.08 g, 60 mmol) and iodine (15.24 g, 60 mmol), and the resulting yellow suspension was stirred at room temperature for 5 min. Alcohol **2** (4.30 g, 50 mmol) was then added as a solution in CH_2Cl_2 (20 mL), and the reaction mixture was stirred at ambient temperature for 3 h. Most of the solvent was removed by rotoevaporation, and the residue was diluted with pentane. The solid was extracted thoroughly with pentane, and the concentrated pentane extracts were passed through a column of silica gel (100 g) eluting with pentane. Concentration of the eluate followed by kugelrohr distillation (air bath 80 °C/30 Torr) provided 8.19 g (84%) of iodide **15** as a light pink oil that became colorless on storage over Cu powder: ^{1}H NMR (200 MHz, $CDCl_3$) δ 4.86 (br s, 1H), 4.75 (br s, 1H), 3.26 (br t, J = 7.5 Hz, 2H), 2.59 (t, J = 7.5 Hz, 2H), 1.74 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 143.8, 112.2, 41.8, 21.6, 3.5; MS(EI) m/z 196 (M^+, 4), 69 (100).

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