Synthesis of Substituted Cyclooctanols by a Samarium(II) Iodide Promoted 8-Endo Radical Cyclization Process

Gary A. Molander* and Jeffrey A. McKie

Department of Chemistry and Biochemistry, University of Colorado, Boulder, Colorado 80309-0215

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Samarium(II) iodide (SmI_2) has been employed to promote an efficient 8-endo radical cyclization reaction of a variety of substituted olefinic ketones. Various substituted monocyclic, fused bicyclic, and bridged bicyclic cyclooctanols have been synthesized in fair to excellent yield via this protocol. In addition to delineating the synthetic potential of this reaction, experiments have been conducted to determine the source of reduced, noncyclized byproducts present in this and related SmI_2-mediated reactions performed under protic conditions.

Introduction

Compounds possessing medium ring substructural units have historically attracted attention because of their potential biological activity and the synthetic challenge posed by the required construction of the carbocycle or heterocycle. The primary difficulty associated with the synthesis of such structures remains the formation of the ring itself because conformational biases inherent in these systems provide some opportunities for stereocontrolled elaboration of substituents once the ring has been generated.[1] While general macrocyclization methods applied to nitrogen heterocycles,[2] lactones,[3] lactams,[4] ethers,[5] and other heterocycles[6] have evolved relatively rapidly, the development of efficient carbon–carbon bond-forming reactions applied to macrocycle synthesis has not proven as easy.[7] General methods for preparing medium-sized carbocycles by simple cyclization reactions of acyclic precursors thus remain relatively scarce.

Somewhat counterintuitively, cyclizations of acyclic precursors generating large ring systems (≥12 membered rings) are typically more facile than the cyclizations forming analogous medium ring (7–11 membered rings) compounds,[8] and even radical cyclization routes to various large ring molecules have proven to be synthetically valuable.[9] Not surprisingly, the synthesis of medium ring macrocycles by radical methods is much less common.[10] In particular, although 8-endo cyclization of a 7-octenyl radical is preferred over the alternative 7-exo mode of cyclization, the accompanying slow cyclization rate of this system has limited its synthetic application.[11] These highly reactive radical intermediates thus undergo competitive hydrogen atom abstraction or disproportionation prior to intramolecular addition to the olefin.

Recently, we reported the ability of samarium(II) iodide–HMPA mixtures to generate unusually persistent ketyl radical anions that participated in various cyclization reactions.[12] Our results indicated the possibility of generating 8-membered rings by an 8-endo radical cyclization process of appropriately substituted keto olefins. Herein we present further studies on the SmI_2-promoted ketyl radical anion cyclization of several unsaturated ketones, affording cyclooctanols. Additionally, we have conducted studies to determine the source of reduced ketone byproducts that occur in some instances under protic conditions.

Results and Discussion

Initial studies were performed to determine optimum reaction conditions for the synthesis of cyclooctanols from appropriately substituted unsaturated ketone substrates. Treatment of 8-nonen-2-one (**1a**) with SmI_2 and 2 equiv of *t*-BuOH in THF resulted in the slow consumption of starting material (eq 1). The single resulting product was 8-nonen-2-ol (**3a**), isolated in 81% yield after 48 h with no evidence of cyclized product (**2a**) present in the reaction mixture. Many SmI_2-promoted reactions benefit from the

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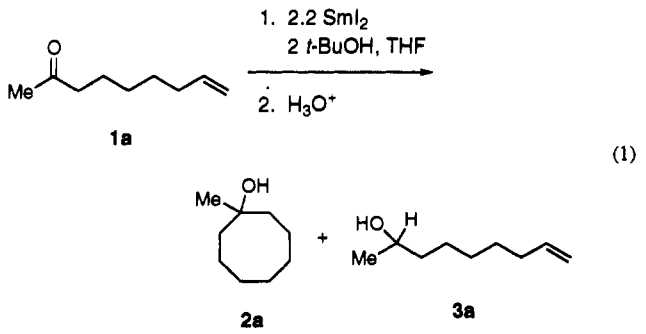
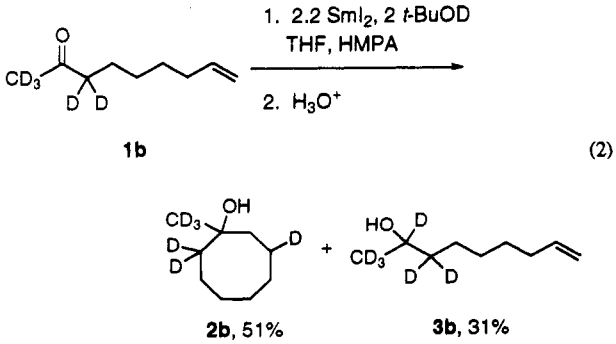


(1)

Conditions	% Yield **2a**	% Yield **3a**
2.2 SmI_2, 2 *t*-BuOH, THF	0	81
2.2 SmI_2, 2 *t*-BuOH, 8 HMPA, THF	54	32
2.2 SmI_2, 2 *t*-BuOH, 8 HMPA, d_8-THF	52	29

presence of HMPA,[13] and indeed our previous study of the SmI_2-mediated ketyl–olefin coupling reaction reaffirmed the essential role of HMPA in these radical cyclization reactions.[12a] In particular, addition of HMPA to the SmI_2-mediated reaction of 8-nonen-2-one resulted in the formation of ketyls exhibiting remarkable persistence, thereby permitting cyclizations impossible to achieve in the absence of this additive.[12a] Thus, the reaction depicted in eq 1 was performed under identical conditions to that previously described, except that 8 equiv of HMPA was added. Under these conditions, cyclooctanol **2a** was isolated in 54% yield, and only 32% of **3a** was generated.

It was initially speculated that the reduced byproduct might be a result of hydrogen atom abstraction from THF.[12a] However, more detailed studies have resulted in our advocation of an alternative pathway for nonproductive quenching of the ketyl radical anion. Hydrogen atom abstraction from THF by a ketyl radical anion is expected to be slightly endothermic.[14] In addition, experiments run in the presence of THF-d_8 and *t*-BuOH resulted in isolation of reduced byproduct **3a** in 29% yield with no deuterium incorporation (eq 1). However, the reduced byproduct **3b** isolated in 31% yield following the cyclization of 1,1,1,3,3-pentadeuterio-8-nonen-2-one (**1b**) in the presence of 2 equiv of *t*-BuOD contained >80% deuterium incorporation at the ketyl center by ^1H and ^2H NMR spectral analysis (eq 2). Furthermore, the amount of



(2)

acyclic alcohol byproduct was found to be proportional to the amount of *t*-BuOH added into the reaction mixture.

(13) Molander, G. A. *Chem. Rev.* **1992**, *92*, 29.

Table 1. Samarium(II) Iodide Promoted 8-Endo Cyclization of Keto Olefins 1

entry	substrate	product	% isolid yield (diastereomeric ratio)
1 (R=Me)	**1c**	**2c**	53 (1:1)
2 (R=*i*-Pr)	**1d**	**2d**	58 (1.5:1)
3 (R=Me)	**1e**	**2e**	54 (3:1)
4 (R=Ph)	**1f**	**2f**	49 (>30:1)
5 (R=*i*-Pr)	**1g**	**2g**	63 (>30:1)
6 (R=Me)	**1h**	**2h**	24 (3:1) [a]
7 (R=Et)	**1i**	**2i**	0
8	**1j**	**2j**	0
9	**1k**	**2k**	0
10	**1l**	**2l**	46 (>30:1)
11	**1m**	**2m**	0

[a] Stereochemistry is not definitive.

In light of these results, the source of hydrogen in the reduced, acyclic byproduct can be narrowed down to either the alcohol additive (which seems most likely) or to intermolecular reaction of ketyls with the ketone starting material or with other ketyl radical anions.[15]

As indicated in Table 1, the unsaturated methyl ketones investigated cyclized in fair yields, but even these yields are remarkable in view of the difficulties normally encountered in the synthesis of eight-membered rings.[12b] Substituents γ to the carbonyl exhibit minimal stereodifferentiating effects in the formation of the corresponding cyclooctanols (entries 1 and 2), while excellent stereoselectivity can be achieved when substituents occupy the

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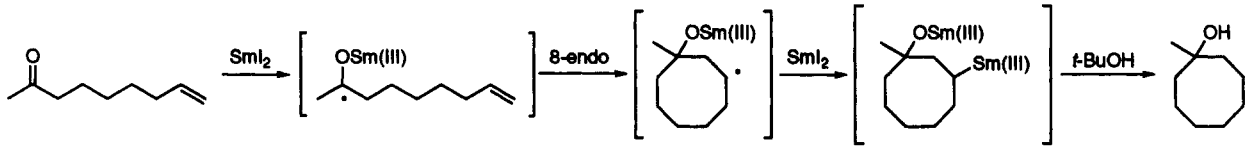
Scheme 1



position β to the carbonyl as indicated by entries 4–5. The major products in the latter cases were the diastereomers exhibiting a trans relationship between the hydroxyl and C-3 substituents.[16] Substituents α to the carbonyl exhibit minimal stereodirecting effects (entry 6). Additionally, this substitution pattern results in a significant decrease in the cyclization rate. In fact, attempted cyclooctanol synthesis using ethyl ketone **1i** (entry 7) or cyclopentanone **1j** (entry 8) failed completely. The major products isolated were the uncyclized unsaturated alcohols resulting from simple reduction of the ketone starting material. Steric congestion about the reaction centers is apparently responsible for these results, slowing cyclization to the point where quenching of the ketyl radical anion is the major reaction pathway. Quite suprisingly, although substrate **1k** (entry 9) was anticipated to experience an accelerated cyclization rate because of the *gem*-dialkyl effect,[8,17] this substrate also reacted much more slowly than expected and only uncyclized, reduced material resulted. Apparently, the additional methyl substituent creates an unfavorable steric effect through transannular interactions that overrides any entropic advantage of having the geminally disubstituted carbon atom in the acyclic chain.[8] In fact, Still has calculated *A* values for methyl substitution at various positions of the boat–chair cyclooctane conformer, and these values can be much higher than the methyl *A* value for cyclohexane.[1] To the extent that these interactions are felt in the transition state leading to cyclooctanol formation in the reaction under study, it is perhaps not surprising that these transannular interactions become serious enough to inhibit cyclization.

Even though they would appear to be even more energetically disfavored, 8-membered bridged bicyclic systems can also be accessed by this radical cyclization reaction as indicated by the successful cyclization of substrate **1l**. Unfortunately, this substitution pattern does not appear to be general. Thus, attempted cyclization of unactivated olefinic substrate **1m** resulted in a slower than normal cyclization rate and only the unsaturated alcohol resulting from simple reduction of the ketone starting material was isolated.

Several different protocols were considered to improve the yields in the cyclization reactions. Initially, use of a solvent that prevented hydrogen abstraction was considered. However, the discovery that the ketyls were not being quenched by hydrogen atom abstraction from THF negated any potential benefits of this approach. In fact, it was recognized that, in principle, far greater benefit could be derived from performing the reactions in the absence of a proton source. Unfortunately, attempted cyclization of several substrates without *t*-BuOH resulted in low yields of the isolated cyclooctanols. Substantial amounts of unidentified products and starting material comprised the majority of the reaction mixture under these conditions. Under the optimized reaction conditions developed above, the intermediate alkoxy cyclooctylsamarium species is immediately quenched by *t*-BuOH. In the absence of *t*-BuOH, this organosamarium can undergo reaction with the ketone starting material or even disproportionation (Scheme 1).[12a]

Other approaches to enhance the conversion of unsaturated ketone to cyclooctyl products were thus considered. In the first approach, substrates were designed that possessed allylically positioned oxygen heteroatoms. This had two potential advantages. The first was that acceleration of the cyclization process was anticipated as a result of olefin activation. In analogy to α-alkoxy radicals, ketyls can be classified as electron-rich, nucleophilic radicals.[18] According to FMO theory the ketyl's SOMO is predicted to interact most efficiently with the unoccupied olefin π^* orbital (LUMO). Therefore, lowering the olefin LUMO should theoretically permit more efficient overlap with the ketyl SOMO and result in a corresponding increase in the observed cyclization rate. One way to accomplish this would be to place an inductively electron-withdrawing heterosubstituent allylic to the olefin. β-Elimination of the heterosubstituent allylic to the olefin provides the second benefit derived from this approach. A rapid β elimination from the intermediate organosamarium avoids the persistence of a highly reactive organosamarium species and thereby removes the need for a proton source in the reaction mixture. Two systems incorporating this strategy were designed and tested. In the first, reaction of substrate **3c** with SmI_2 in THF/HMPA resulted in the isolation of **4c** in 72% yield, with none of the acyclic reduced alcohol generated (Scheme 2). The only reasonable manner in which this product can be formed is via an 8-endo radical cyclization, followed by β-elimination of the alkoxy group from the organosamarium intermediate. The same reaction performed in the presence of 2 equiv of *t*-BuOH resulted in isolation of 51% of the desired cyclized fragmented product (**4c**) in addition to 28% of acyclic alcohol. These results provide further evidence that a majority of the reduced, uncyclized starting material is a result of overall two-electron reduction of the ketone functionality, with protonation of the intermediate carbanion by alcohol present in the reaction mixture.[19]

The second system examined was substrate **3d**, which permitted isolation of cyclooctenol product **4d** in 81% yield (Table 2, entry 1). There was no evidence of reduced, uncyclized material in this case.

Another potential means to enhance cyclization is the placement of an electron-withdrawing or π-conjugating

(16) An X-ray crystal structure of the 3,5-dinitrobenzoate ester of alcohol **2f** has been resolved, supporting the indicated stereochemistry (see supplementary material).

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(19) Our results do not distinguish between protonation of a dianionic alcoholate intermediate or protonation of a monoanionic hydroxy carbanion as proposed by House. House, H. O. *Modern Synthetic Reactions*; Benjamin: Menlo Park, 1972.

Scheme 2

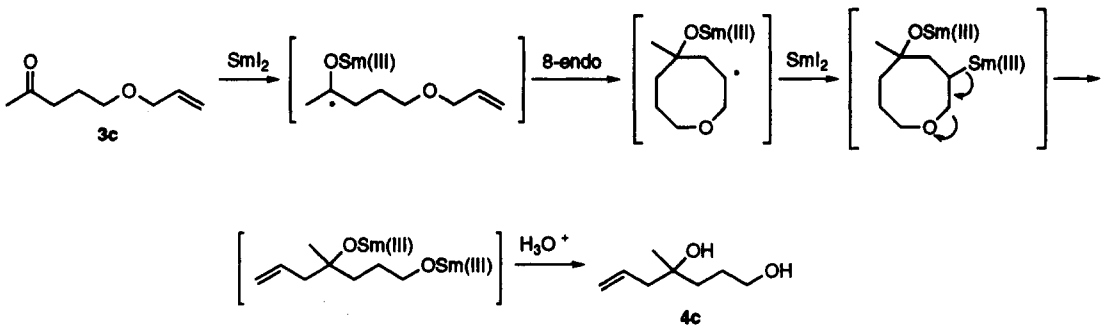
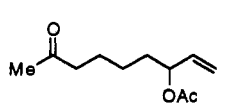
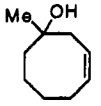
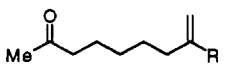
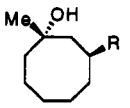
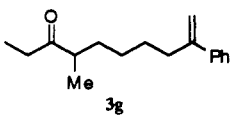
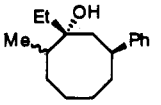
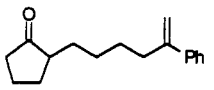
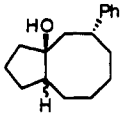
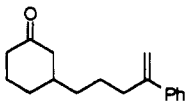
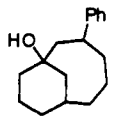
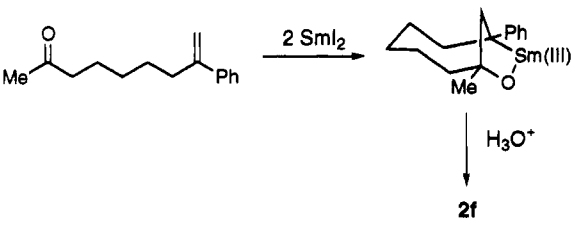


Table 2. 8-Endo Radical Cyclization of Substituted Keto Olefins 3

entry	substrate	product	% isoltd yield (diastereomeric ratio)
1	 3d	 4d	81
2 (R=Me)	 3e	 2e	31 (2:1)
3 (R=Ph)	3f	2f	91 (>30:1)
4	 3g	 4g	86 (2:1)
5	 3h	 4h	78 (1:1)
6	 3i	 4i	78 (6:1) [a]

[a] The relative stereochemistry of the two diastereomers is uncertain.

substituent directly on the olefin, again with the idea of increasing radical–SOMO/alkene–LUMO interactions in the transition state leading to product. A simple way to test this idea was to place an aryl substituent on the alkene, which provided a benzylically-stabilized radical intermediate en route from the acyclic substrates to the cyclooctanol products. As indicated in Table 2, all substrates possessing this substitution pattern cyclized in good to excellent yield, including otherwise analogous substrates that did not cyclize without the stabilization provided by the phenyl group (entries 4 and 6). Interestingly, there is a preference for the hydroxyl and phenyl substituents to exist in an anti-relationship in the final products. A possible explanation for this observation is that the alkoxide functionality complexes the samarium(III) ion associated with the stabilized benzylic carbanion, creating a preference for one diastereomeric organometallic intermediate. Protonation from the side of the metal center then affords the observed relative stereochemisty (eq 3). With appropriate substitution about the olefin, monocyclic, fused bicyclic, as well as bridged bicyclic systems can all be prepared in excellent yield.



(3)

Conclusions

The samarium(II) iodide promoted 8-endo cyclization of various keto olefins in the presence of HMPA affords a variety of 8-membered ring products in fair to excellent yields. Experiments have demonstrated that THF is not the hydrogen source responsible for byproduct formation from ketone reduction without cyclization. Rather, the byproduct alcohol arises as a result of protonation of an intermediate carbanion formed from two-electron reduction of the ketone functionality in the substrate. These results imply that switching to a non-hydrogen atom donating solvent is a futile solution to minimizing byproduct formation. However, substrates that do not require protonation of the intermediate carbanion following cyclization, or substrates with relatively low-lying olefin π^* orbitals, afford excellent yields of 8-membered ring products. The role of HMPA is less definitive. However, it is certain that samarium(III) ketyls generated in the presence of this additive are more persistent, perhaps because the HMPA excludes the proton source from the coordination sphere of the Sm(III) ion, thereby resulting in a longer-lived reactive intermediate.

Research continues to outline the scope of this process, in particular with regard to substituents and substitution patterns about the precursors that will lead to high yields and enhanced stereochemical control in the cyclization process.

Experimental Section

Reagents. Tetrahydrofuran (THF) was distilled immediately prior to use from benzophenone ketyl under Ar. Samarium metal was purchased from Cerac, Inc., Milwaukee, WI, and was weighed and stored under an inert atmosphere. CH_2I_2 was purchased from Aldrich and was distilled prior to use. Standard benchtop techniques were employed for handling air-sensitive reagents, and all reactions were carried out under Ar.

5-Methyl-8-nonen-2-one (1c). To a suspension of CuCN (1.26 g, 14 mmol) in 15 mL of THF was added TMEDA (1.63 g, 14

mmol). The mixture was allowed to stir for 10 min at room temperature, and then it was cooled to −78 °C. 5-Hexenyl-2-magnesium bromide (15 mmol, 15 mL of a 1 M in THF) was added dropwise over 5 min, and the resulting light yellow suspension was stirred for an additional 20 min. TMSCl (1.30 g, 12 mmol) was added followed by a precooled solution of 3-buten-2-one (0.84 g, 12 mmol) in 10 mL of THF. Upon complete reaction (ca. 30 min), the reaction mixture was quenched with aqueous NH_4Cl/NH_4OH (10:1). Extractive workup (Et_2O) afforded the TMS enol ether that was hydrolyzed in 1 M HCl. Flash chromatography yielded the title compound (1.41 g, 61%). ^1H NMR (300 MHz, $CDCl_3$): δ 5.82–5.67 (m, 1H), 4.97–4.85 (m, 2H), 2.43–2.36 (m, 2H), 2.09 (s, 3H), 2.04–1.93 (m, 2H), 1.61–1.12 (m, 5H), 0.82 (d, J = 6.4 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 209.36, 138.94, 114.19, 41.32, 35.77, 31.73, 31.09, 30.46, 29.76, 19.09.

5-Bromo-6-methyl-1-heptene. To a solution of 3-butenylmagnesium bromide (ca. 50 mmol) in 100 mL of THF at −30 °C was added a solution of 2-methyl-1-propanal (2.88 g, 40 mmol) in 100 mL of THF over 1 h. The resulting suspension was allowed to stir 1 h prior to an aqueous workup. The isolated crude alcohol was dissolved in 150 mL of CH_2Cl_2, triethylamine (4.55 g, 45 mmol) was added, and the solution was cooled to −10 °C. Following slow addition of MsCl (4.58 g, 40 mmol) the reaction mixture was warmed to 0 °C and stirred for 3 h. Aqueous workup yielded the crude methanesulfonate. Displacement of the methanesulfonate with NaBr (10.3 g, 100 mmol) in 100 mL of DMF heated at 60 °C produced the crude title compound. The crude product was purified by distillation (95 °C at 60 mmHg) to afford material (5.38 g, 47%) >98% pure (GC, NMR). ^1H NMR (300 MHz, $CDCl_3$): δ 5.84–5.69 (m, 1H), 5.13–4.94 (m, 2H), 4.03–3.92 (m, 1H), 2.39–1.78 (m, 5H), 1.01 (d, J = 6.6 Hz, 3H), 0.96 (d, J = 6.6 Hz, 3H).

5-(2-Propyl)-8-nonen-2-one (1d). Following the conjugate addition procedure described for **1c**, 6-heptenyl-3-magnesium bromide was added to 3-buten-2-one to afford the title compound in 52% yield. ^1H NMR (300 MHz, $CDCl_3$): δ 5.83–5.67 (m, 1H), 5.01–4.86 (m, 2H), 2.38 (t, J = 7.9 Hz, 2H), 2.11 (s, 3H), 2.04–1.93 (m, 2H), 1.73–1.04 (m, 6H), 0.81 (d, J = 7.0 Hz, 6H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 209.50, 139.09, 114.29, 42.57, 41.98, 31.72, 29.82, 29.38, 28.88, 24.17, 18.94, 18.88.

4-Methyl-8-nonen-2-one (1e). Following the conjugate addition procedure described for **1c**, 4-pentenylmagnesium bromide was added to 3-penten-2-one to afford the title compound in 66% yield. ^1H NMR (300 MHz, $CDCl_3$): δ 5.78–5.63 (m, 1H), 4.94–4.82 (m, 2H), 2.33 (dd, J = 15.9, 5.6 Hz, 1H), 2.15 (dd, J = 15.9, 7.8 Hz, 1H), 2.04 (s, 3H), 1.99–1.86 (m, 2H), 1.37–1.04 (m, 5H), 0.81 (d, J = 6.6 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 208.90, 138.68, 114.30, 51.02, 36.13, 33.67, 30.22, 28.92, 26.07, 19.58.

4-Phenyl-8-nonen-2-one (1f). Following the conjugate addition procedure described for **1c**, 4-pentenylmagnesium bromide was added to 4-phenyl-3-buten-2-one to afford the title compound in 65% yield. ^1H NMR (300 MHz, $CDCl_3$): δ 7.31–7.14 (m, 5H), 5.75–5.61 (m, 1H), 4.94–4.85 (m, 2H), 3.14–3.04 (m, 1H), 2.69–2.66 (m, 2H), 1.97 (s, 3H), 1.64–1.48 (m, 2H), 1.30–1.48 (m, 2H), 1.30–1.10 (m, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 207.75, 144.34, 138.52, 128.40, 127.38, 126.28, 114.43, 50.75, 41.00, 35.71, 33.45, 30.47, 26.49.

4-(2-Propyl)-8-nonen-2-one (1g). Following the conjugate addition procedure described for **1c**, 4-pentenylmagnesium bromide was added to 5-methyl-3-hexen-2-one to afford the title compound in 73% yield. ^1H NMR (300 MHz, $CDCl_3$): δ 5.79–5.62 (m, 1H), 4.97–4.81 (m, 2H), 2.32 (dd, J = 16.4, 5.6 Hz, 1H), 2.16 (dd, J = 16.4, 7.6 Hz, 1H), 2.07 (s, 3H), 1.96–1.59 (m, 4H), 1.31–1.04 (m, 4H), 0.77 (d, J = 6.8 Hz, 3H), 0.74 (d, J = 6.8 Hz, 3H).

3-Methyl-8-nonen-2-one (1h). To a solution of LDA (12 mmol) in 20 mL of THF at 0 °C was added the *N,N*-dimethylhydrazone of propanal (1.0 g, 10 mmol) in 15 mL of THF. The resulting suspension was allowed to stir for 2 h at 0 °C, at which time 6-bromo-1-hexene (1.96 g, 12 mmol) was added. After being warmed to room temperature the reaction mixture was stirred for an additional 2 h. Aqueous workup afforded the crude alkylated hydrazone. The hydrazone was dissolved in 50 mL of acetone, and 5 g of wet Amberlyst ion-exchange resin was added. After the reaction mixture was stirred for 6 h at room temperature, 100 mL of Et_2O was added, and the ion-exchange residue was removed by filtration. The organic layer was dried, concentrated, and purified via flash chromatography. The resulting aldehyde was dissolved in 20 mL of THF and cooled to −78 °C. MeLi (14 mmol, 10 mL of a 1.4 M solution in Et_2O) was added, and the resulting suspension was gradually warmed to 0 °C over 30 min. The reaction mixture was stirred for 2 h at 0 °C, and an aqueous workup was performed. The resulting crude alcohol was dissolved in 30 mL of acetone and was oxidized to the corresponding methyl ketone with PDC (5.64 g, 15 mmol). Aqueous workup followed by flash chromatography afforded the title compound (0.76 g, 49%). ^1H NMR (300 MHz, $CDCl_3$): δ 5.81–4.64 (m, 1H), 4.98–4.84 (m, 2H), 2.50–2.38 (m, 1H), 2.07 (s, 3H), 2.02–1.93 (m, 2H), 1.65–1.15 (m, 6H), 1.01 (d, J = 6.8 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 212.82, 138.67, 114.38, 47.01, 33.43, 32.57, 28.76, 27.84, 26.52, 16.04.

4-Methyl-9-decen-3-one (1i). Following the hydrazone alkylation procedure described for **1h**, the title compound was prepared in 86% yield from 3-pentanone *N,N*-dimethylhydrazone and 6-bromo-1-hexene. ^1H NMR (300 MHz, $CDCl_3$): δ 5.82–5.68 (m, 1H), 5.02–4.87 (m, 2H), 2.49–2.05 (m, 3H), 2.07–1.96 (m, 2H), 1.67–1.57 (m, 1H), 1.40–1.18 (m, 5H), 1.03 (d, J = 6.8 Hz, 3H), 1.01 (t, J = 7.3 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 215.54, 138.76, 114.36, 45.95, 34.12, 33.46, 32.82, 28.80, 26.66, 16.38, 7.66.

2-(5-Hexenyl)cyclopentan-1-one (1j). Following the hydrazone alkylation procedure described for **1h**, the title compound was prepared in 92% yield from cyclopentanone *N,N*-dimethylhydrazone and 6-bromo-1-hexene. ^1H NMR (300 MHz, $CDCl_3$): δ 5.83–5.71 (m, 1H), 5.01–4.86 (m, 2H), 2.32–1.19 (m, 15H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 221.60, 138.85, 114.35, 49.06, 38.09, 33.50, 29.51, 29.43, 28.75, 26.94, 20.67.

4,4-Dimethyl-8-nonen-2-one (1k). Following the conjugate addition procedure described for **1c**, 4-pentenylmagnesium bromide was added to 4-methyl-3-penten-2-one to afford the title compound in 61% yield. ^1H NMR (300 MHz, $CDCl_3$): δ 5.82–5.67 (m, 1H), 5.01–4.85 (m, 2H), 2.28 (s, 2H), 2.08 (s, 3H), 2.01–1.94 (m, 2H), 1.32–1.26 (m, 4H), 0.94 (s, 6H).

3-Methyl-3-(4-pentenyl)cyclohexan-1-one (1l). Following the conjugate addition procedure described for **1c**, 4-pentenylmagnesium bromide was added to 3-methyl-2-cylohexen-1-one to afford the title compound in 80% yield. ^1H NMR (300 MHz, $CDCl_3$): δ 5.82–5.69 (m, 1H), 4.99–4.89 (m, 2H), 2.27–1.20 (m, 14H), 0.87 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 212.34, 138.64, 114.63, 53.74, 40.98, 38.48, 35.76, 34.20, 24.99, 22.65, 22.05.

3-(4-Pentenyl)cyclohexan-1-one (1m). Following the general conjugate addition procedure described for **1c**, 4-pentenylmagnesium bromide was added to 2-cylohexen-1-one to afford the title compound in 83% yield. ^1H NMR (300 MHz, $CDCl_3$): δ 5.79–5.64 (m, 1H), 4.96–4.85 (m, 2H), 2.48–2.13 (m, 3H), 2.04–1.49 (m, 7H), 1.37–1.18 (m, 5H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 211.86, 138.46, 114.47, 47.99, 41.32, 38.80, 35.82, 33.54, 31.08, 25.74, 25.10.

6-Oxa-8-nonen-2-one (3c). To a solution of 5-hydroxy-2-pentanone (1.02 g, 10 mmol) in 20 mL of acetone was added allyl bromide (3.63 g, 30 mmol) and $CaSO_4$ (10 g). Ag_2O (3.72 g, 15 mmol) was added in several portions over 30 min, and the suspension was stirred overnight. Addition of Et_2O followed by filtration, solvent removal, and flash chromatography afforded the title compound (0.92 g, 65%). ^1H NMR (400 MHz, $CDCl_3$): δ 5.88–5.79 (m, 1H), 5.20 (dd, J = 17.2, 1.5 Hz, 1H), 5.11 (dd, J = 10.4, 1.5 Hz, 1H), 3.88 (d, J = 5.6 Hz, 2H), 3.77 (t, J = 6.2 Hz, 2H), 2.49 (t, J = 7.2 Hz, 2H), 2.09 (s, 3H), 1.85–1.76 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 208.56, 134.70, 116.73, 71.64, 69.11, 40.20, 29.89, 23.75.

6,6-(Ethylenedioxy)-1-heptanal. To a solution of 7-octen-2-one (1.26 g, 10 mmol) in 25 mL of benzene in a 100-mL round-bottom flask fitted with a Dean-Stark trap was added ethylene glycol (1.24 g, 20 mmol) and *p*-TsOH (0.01 g). The resulting solution was heated at reflux for 3 h. Aqueous workup afforded the crude acetal. The resulting acetal was dissolved in 30 mL of a CH_2Cl_2:MeOH (5:1) mixture, and $NaHCO_3$ (0.05 g) was added. The solution was cooled to −78 °C, and O_3 was bubbled through the solution until a faint blue color persisted. Argon was then bubbled through the solution to remove excess O_3, Bu_3P (3.15 g,

12 mmol) was added, and the reaction mixture was allowed to warm to 0 °C. After 2 h aqueous workup and flash chromatography afforded the title compound (1.25 g, 73%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 9.74 (s, 1H), 3.92–3.74 (m, 4H), 2.42 (t, J = 7.1 Hz, 2H), 1.61–1.51 (m, 4H), 1.37–1.25 (m, 2H), 1.28 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 202.65, 109.71, 64.47, 43.68, 38.73, 23.58, 23.43, 22.04.

8-Oxo-1-nonenyl 3-Acetate (3d). To a solution of 6,6-(ethylenedioxy)-1-heptanal (0.86 g, 5 mmol) in 20 mL of THF cooled to −78 °C was added vinylmagnesium bromide (7 mmol, 3.5 mL of a 2.0 M solution in Et_2O). After 3 h at −78 °C aqueous workup yielded the expected crude allylic alcohol. The acetal was removed with 1 M HCl (10 mL) in 30 mL of THF at 0 °C. The isolated crude hydroxy ketone was acetylated in CH_2Cl_2 (20mL) with Ac_2O (1.02 g, 10 mmol), triethylamine (1.01 g, 10 mmol), and DMAP (0.1 g) at 0 °C for 3 h. Aqueous workup and flash chromatography afforded the title compound (0.60 g, 61%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 5.79–5.65 (m, 1H), 5.23–5.08 (m, 3H), 2.39 (t, J = 7.3 Hz, 2H), 2.08 (s, 3H), 2.01 (s, 3H), 1.64–1.49 (m, 4H), 1.32–1.21 (m, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 208.77, 170.34, 136.36, 116.70, 74.48, 43.38, 33.85, 29.79, 24.51, 23.32, 21.13.

6,6-(Ethylenedioxy)-1-iodoheptane. To a solution of LDA (22 mmol) in 40 mL of THF at 0 °C was added the *N,N*-dimethylhydrazone of acetone (2.0 g, 20 mmol). After 2 h, 4-chloro-1-iodobutane (4.81 g, 22 mmol) was added, and the solution was allowed to stir for an additional 3 h. Aqueous workup, followed by hydrazone cleavage (Amberlyst, acetone) afforded crude 8-chloro-2-heptanone. This crude product was protected as the acetal (ethylene glycol) as described previously. Finkelstein reaction yielded the title compound (3.20 g, 56%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.93–3.87 (m, 4H), 3.15 (t, J = 7.1 Hz, 2H), 1.85–1.73 (m, 2H), 1.64–1.58 (m, 2H), 1.1–1.34 (m, 4H), 1.27 (s, 3H).

8-Methyl-8-nonen-2-one (3e). To a solution of 2-bromopropene (1.21 g, 10 mmol) in 30 mL of THF at −78 °C was added *n*-BuLi (11 mmol, 6.9 mL of a 1.6 M solution in hexanes), and the resulting solution was stirred for 2 h. 6,6-(Ethylenedioxy)-1-iodoheptane was added (2.84 g, 10 mmol), and the reaction mixture was allowed to gradually warm to room temperature. After 4 h at room temperature, aqueous workup followed by acetal cleavage (1 M HCl, THF) and purification by flash chromatography yielded the title compound (1.20 g, 78%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.68–4.62 (m, 2H), 2.40 (t, J = 7.2 Hz, 2H), 2.10 (s, 3H), 1.97 (t, J = 7.2 Hz, 2H), 1.67 (s, 3H), 1.62–1.21 (m, 6H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 209.38, 145.95, 109.75, 43.67, 37.50, 29.82, 28.70, 27.25, 23.62, 22.27.

8-Phenyl-8-nonen-2-one (3f). Following the procedure described for **3e**, (1-phenylethenyl)lithium (generated by reaction of α-bromostyrene with *n*-BuLi) was coupled with 6,6-(ethylenedioxy)-1-iodoheptane to provide the title compound in 64% yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.39–7.20 (m, 5H), 5.21 (d, J = 1.0 Hz, 1H), 5.00 (d, J = 1.0 Hz, 1H), 2.45 (t, J = 7.3 Hz, 2H), 2.35 (t, J = 7.4 Hz, 2H), 2.07 (s, 3H), 1.56–1.24 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 209.22, 148.38, 141.20, 128.21, 127.25, 126.05, 112.21, 43.62, 35.07, 29.85, 28.71, 27.88, 23.54.

2-Phenyl-6-iodo-1-hexene. To a solution of α-bromostyrene (3.66 g, 20 mmol) in 40 mL of THF at −78 °C was added *n*-BuLi (22 mmol, 13.8 mL of a 1.6 M solution in hexanes), and the burgundy solution was allowed to stir for 1 h. 1-Chloro-4-iodobutane (5.46 g, 25 mmol) was added, and the resulting solution was gradually warmed to room temperature. After an additional 4 h at room temperature, aqueous workup afforded crude 2-phenyl-6-chloro-1-hexene. Heating this crude product with NaI (9.0 g, 60 mmol) in 100 mL of acetone at reflux for 14 h followed by aqueous workup and flash chromatography yielded the title compound (3.3 g, 58%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.39–7.22 (m, 5H), 5.23 (d, J = 1.2 Hz, 1H), 5.03 (d, J = 1.2 Hz, 1H), 3.12 (t, J = 7.1 Hz, 2H), 2.49 (t, J = 7.3 Hz, 2H), 1.84–1.51 (m, 4H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 147.79, 140.91, 128.31, 127.41, 126.08, 112.68, 34.08, 32.95, 28.87, 6.63.

4-Methyl-9-phenyl-9-decen-3-one (3g). Following the hydrazone alkylation procedure described for **1h**, the title compound was prepared in 93% yield from 3-pentanone *N,N*-dimethylhydrazone and 2-phenyl-6-iodo-1-hexene. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.41–7.26 (m, 5H), 5.23 (d, J = 1.5 Hz, 1H), 5.02 (d, J = 1.5 Hz, 1H), 2.51–2.36 (m, 5H), 1.64–1.22 (m, 6H), 1.02 (d, J = 7.1 Hz, 3H), 1.01 (t, J = 7.3 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 215.45, 148.44, 141.27, 128.24, 127.29, 126.09, 112.25, 45.93, 35.08, 34.18, 32.81, 28.15, 26.87, 16.42, 7.70.

2-(5-Phenyl-5-hexenyl)cyclopentanone (3h). Following the hydrazone alkylation procedure described for **1h**, the title compound was prepared in 48% yield from cyclopentanone *N,N*-dimethylhydrazone and 2-phenyl-6-iodo-1-hexene. ^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.42–7.23 (m, 5H), 5.26 (d, J = 1.3 Hz, 1H), 5.04 (d, J = 1.3 Hz, 1H), 2.51 (t, J = 7.3 Hz, 2H), 2.34–1.18 (m, 13H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 221.66, 148.48, 141.28, 128.23, 127.28, 126.09, 112.20, 49.03, 38.10, 35.04, 29.48, 29.35, 28.02, 27.08, 20.66.

3-(4-Phenyl-4-pentenyl)cyclohexanone (3i). Following the conjugate addition procedure described for **1c**, 4-phenyl-4-pentenylmagnesium chloride was added to 2-cyclohexenone to afford the title compound in 58% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.42–7.22 (m, 5H), 5.26 (d, J = 1.5 Hz, 1H), 5.04 (d, J = 1.5 Hz, 1H), 2.49–1.22 (m, 15H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 211.93, 148.29, 141.16, 128.24, 127.32, 126.05, 112.33, 48.08, 41.38, 38.82, 36.03, 35.21, 31.12, 25.14, 25.07.

Preparation of SmI_2 Solution. Samarium metal (0.301 g, 2.00 mmol) was added under a flow of Ar to an oven-dried round-bottomed flask containing a magnetic stirring bar and a septum inlet. To the samarium was added 12 mL of THF followed by CH_2I_2 (0.492 g, 1.84 mmol). The mixture was stirred at room temperature for 2 h. The resulting deep blue solution was used directly to effect the following reductive cyclization reactions.

General Procedure for 8-Endo Radical Cyclization of Olefinic Ketones. To the SmI_2 (1.84 mmol) in THF was added HMPA (2.63 g, 17.4 mmol), and Ar was bubbled through the solution for 10 min. A solution of the olefinic ketone (0.83 mmol) and *t*-BuOH (1.64 mmol) in 40 mL of THF was added over 1.5 h. After the starting material was consumed, aqueous workup followed by flash chromatography and/or Kugelrohr distillation afforded the title compounds.

1,4-Dimethylcyclooctan-1-ol (2c). (**1c**, 0.154 g, 1.00 mmol) yield 0.083 g (53%) as a ca. 1:1 mixture of diastereomers. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.85–0.95 (m, 14H), 1.16 (s, 1.5H), 1.14 (s, 1.5H), 0.84 (d, J = 6.3 Hz, 1.5H), 0.83 (d, J = 6.6 Hz, 1.5H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 73.39, 73.32, 37.78, 37.75, 37.62, 36.60, 34.00, 33.51, 33.06, 32.48, 30.94, 30.86, 30.24, 29.22, 25.99, 25.90, 24.17, 23.78, 22.88, 22.50. IR (CCl_4): 3605, 3429, 2921, 2857 cm^{-1}. LRMS (EI) *m/e*: 156 (1), 141 (7), 96 (31), 70 (100), 58 (24), 43 (40). Anal. Calcd for $C_{10}H_{20}O$: C, 76.86; H, 12.90. Found: C, 76.54; H, 12.98.

1-Methyl-4-(2-propyl)cyclooctan-1-ol (2d). (**1d**, 0.051 g, 0.28 mmol) yield, 0.30 g (58%) as a 1.5:1 mixture of diastereomers. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.92–1.14 (m, 15H), 1.18 (s, 1.8H), 1.16 (s, 1.2H), 0.81 (d, J = 6.6 Hz, 3H), 0.80 (d, J = 6.8 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 73.73, 73.51, 44.17, 44.00, 39.01, 38.53, 37.38, 36.81, 34.14, 34.01, 31.03, 29.09, 28.40, 28.33, 27.89, 26.00, 25.46, 23.15, 22.86, 19.66, 19.54, 19.20, 19.17. IR (CCl_4): 3605, 3422, 2935, 2864 cm^{-1}. LRMS (EI) *m/e*: (major), 184 (1), 169 (5), 124 (22), 95 (24), 71 (100), 58 (30), 43 (70); (minor) 184 (3), 169 (4), 124 (31), 95 (16), 71 (100), 58 (39), 43 (74). Anal. Calcd for $C_{12}H_{24}O$: C, 78.20; H, 13.12. Found: C, 78.08; H, 13.11.

1,3-Dimethylcyclooctan-1-ol (2e). (**1e**, 0.151 g, 0.98 mmol) yield 0.083 g (54%) as a 3:1 mixture of diastereomers. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.87–1.22 (m, 14H), 1.17 (s, 2.25H), 1.15 (s, 0.75H), 0.88 (d, J = 6.9 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): (major) δ 73.49, 45.68, 38.98, 35.58, 29.50, 28.79, 28.72, 25.02, 23.00, 22.26; (minor) δ 73.12, 47.53, 38.15, 37.27, 30.65, 27.32, 26.70, 26.27, 23.63, 22.95. IR (CCl_4): 3605, 3407, 2921, 2864 cm^{-1}. LRMS (EI) *m/e*: (major) 156 (2), 141 (21), 85 (100), 71 (79), 58 (52), 43 (58); (minor) 156 (1), 141 (17), 85 (100), 71 (62), 58 (47), 43 (56). Anal. Calcd for $C_{10}H_{20}O$: C, 76.86; H, 12.84. Found: C, 76.80; H, 12.90.

(1*R,3*R**)-1-Methyl-3-phenylcyclooctan-1-ol (2f).** (**1f**, 0.225 g, 1.04 mmol) yield 0.110 g (49%) as a single diastereomer, mp 87–89 °C. Recrystallization of the 3,5-dinitrobenzoate ester from EtOH provided crystals suitable for X-ray structure determination. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.38–7.19 (m, 5H), 3.13–3.08 (m, 1H), 2.21 (dd, J = 15.1, 7.9 Hz, 1H), 2.04 (dd, J = 14.0, 12.0 Hz, 1H), 1.91–1.59 (m, 10H), 1.85 (d, J = 15.1 Hz, 1H), 1.27 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 151.27, 128.42, 126.84,

125.44, 72.91, 47.78, 39.22, 38.72, 36.48, 30.79, 26.20, 24.03, 22.68. IR (CCl_4): 3605, 3344, 3048, 2914 cm^{-1}. HRMS: calcd for $C_{15}H_{22}O$ 200.1566 (M - H_2O), found 200.1566. LRMS (EI) *m/e*: 203 (3), 200 (81), 172 (60), 147 (68), 118 (62), 104 (83), 91 (100), 71 (73), 43 (75). Anal. Calcd for $C_{15}H_{22}O$: C, 82.52; H, 10.16. Found: C, 82.63; H, 10.32.

(1*R,3*R**)-1-Methyl-3-(2-propyl)cyclooctan-1-ol (2g).** (**1g**, 0.198 g, 1.05 mmol) yield 0.122 g (63%) as a single diastereomer by GC and NMR analyses. ^1H NMR (300 MHz, $CDCl_3$): δ 1.74–1.16 (m, 15H), 1.15 (s, 3H), 0.80 (d, J = 6.9 Hz, 3H), 0.78 (d, J = 6.9 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 73.71, 42.46, 39.81, 37.62, 34.98, 32.76, 29.67, 27.33, 24.12, 21.84, 19.37, 18.77. IR (CCl_4): 3605, 3386, 2928, 2864 cm^{-1}. HRMS: calcd for $C_{12}H_{24}O$ 184.1827, found 184.1832. LRMS (CI+) *m/e*: 183 (20), 167 (92), 141 (61), 111 (98), 97 (100), 83 (72), 41 (90). Anal. Calcd for $C_{12}H_{24}O$: C, 78.20; H, 13.12. Found: C, 78.31; H, 13.24.

1,2-Dimethylcyclooctan-1-ol (2h). (**1h**, 0.136 g, 0.88 mmol) yield 0.033 g (24%) as a 3:1 mixture of diastereomers: ^1H NMR (300 MHz, $CDCl_3$): δ 1.94–1.19 (m, 14H), 1.17 (s, 0.75H), 1.12 (s, 2.25H), 0.93 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): (major) δ 75.34, 40.95, 36.91, 32.77, 29.12, 27.12, 25.82, 22.98, 21.69, 17.49; (minor) δ 74.68, 38.99, 38.95, 31.34, 29.06, 27.07, 26.95, 25.52, 23.39, 17.96. IR (CCl_4): 3612, 3492, 2921, 2857 cm^{-1}. LRMS (EI) *m/e*: (major) 156 (4), 141 (9), 85 (46), 71 (100), 58 (34), 43 (60); (minor) 156 (8), 141 (12), 85 (33), 71 (100), 58 (37), 43 (56). Anal. Calcd for $C_{10}H_{20}O$: C, 76.86; H, 12.90. Found: C, 77.15; H, 12.77.

(1*R,7*R**)-7-Methylbicyclo[5.3.1]undecan-1-ol (2i).** (**1i**, 0.180 g, 1.00 mmol) yield 0.084 g (46%): mp 58–59 °C. ^1H NMR (300 MHz, $CDCl_3$): δ 1.98–1.01 (m, 18H), 0.84 (br s, 1H), 0.78 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 72.70, 43.59, 40.56, 38.52, 38.04, 35.50, 33.90, 32.11, 32.01, 23.05, 22.39, 20.43. IR (CCl_4): 3603, 3407, 2921, 2857 cm^{-1}. HRMS: calcd for $C_{12}H_{22}O$ 182.1671, found 182.1673. LRMS (EI) *m/e*: 182 (2), 167 (17), 139 (68), 111 (100), 55 (62), 41 (75). Anal. Calcd for $C_{12}H_{22}O$: C, 79.06; H, 12.16. Found: C, 78.98; H, 11.98.

4-Methyl-6-hepten-1,4-diol (4c). (**3c**, 0.148 g, 1.04 mmol) yield 0.076 g (51%, 2 equiv of *t*-BuOH added). (**3c**, 0.109 g 0.77 mmol) yield 0.80 g (72% no *t*-BuOH added). ^1H NMR (300 MHz, $CDCl_3$): δ 5.89–5.74 (m, 1H), 5.11–5.02 (m, 2H), 3.58 (t, J = 6.1 Hz, 2H), 3.11 (br s, 2H), 2.20 (d, J = 7.6 Hz, 2H), 1.68–1.49 (m, 4H), 1.13 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 134.05, 118.47, 71.79, 62.92, 46.59, 38.34, 26.76, 26.48. IR (CCl_4): 3346, 2910 cm^{-1}. HRMS: calcd for $C_8H_{16}O_2$ 145.1235 (M + 1), found 145.1150. LRMS (EI) *m/e*: 145 (M + 1) (5), 127 (35), 109 (78), 85 (95), 67 (54), 43 (100). Anal. Calcd for $C_8H_{16}O_2$: C, 66.63; H, 11.18. Found: C, 66.57; H, 10.98.

***cis*-1-Methyl-3-cyclooctene-1-ol (4d).** (**3d**, 0.194 g, 0.98 mmol) yield 0.111 g (81%, no *t*-BuOH added). ^1H NMR (300 MHz, $CDCl_3$): δ 5.74 (dt, J = 10.5, 7.8 Hz, 1H), 5.59 (dt, J = 10.5, 8.3 Hz, 1H), 2.31 (dd, J = 12.9, 8.3 Hz, 1H), 2.12 (dd, J = 12.9, 7.8 Hz, 1H), 2.20–2.02 (m, 2H), 1.64–1.37 (m, 7H), 1.18 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 132.80, 127.33, 75.40, 40.27, 38.30, 29.45, 29.02, 26.52, 22.88. IR (CCl_4): 3605, 3407, 2923, 1553 cm^{-1}. HRMS: calcd for $C_9H_{16}O$ 140.1201, found 140.1202. LRMS (EI) *m/e*: 140 (12), 97 (35), 82 (40), 71 (85), 43 (100).

1,3-Dimethylcyclooctan-1-ol (2e). (**3e**, 0.123 g, 0.80 mmol), yield 0.039 g (31%) as a 2:1 mixture of diastereomers identical in every respect with **2e** above.

(1*R,3*R**)-1-Methyl-3-phenylcyclooctan-1-ol (2f).** (**3f**, 0.181 g, 0.84 mmol) yield 0.165 g (91%) as a single diastereomer identical in every respect with **2f** above.

1-Ethyl-2-methyl-7-phenylcyclooctan-1-ol (4g). (**3g**, 0.232 g, 0.95 mmol) yield 0.201 g (86%) as a 2:1 mixture of diastereomers (separable). ^1H NMR (300 MHz, $CDCl_3$): (major) δ 7.38–7.16 (m, 5H), 3.04–2.96 (m, 1H), 2.32–2.21 (m, 1H), 2.10 (dd, J = 15.3, 7.5 Hz, 1H), 1.93 (dd, J = 15.3, 0.9 Hz, 1H), 1.92–1.35 (m, 10H), 1.27 (br s, 1H), 0.99 (d, J = 6.9 Hz, 3H), 0.83 (t, J = 7.5 Hz, 3H); (minor, C_6D_6) δ 7.23–7.05 (m, 5H), 3.58–3.47 (m, 1H), 2.46–2.31 (m, 1H), 2.08 (dd, J = 14.9, 7.8 Hz, 1H), 1.78–1.41 (m, 8H), 1.64 (dd, J = 14.9, 1.5 Hz, 1H), 1.21 (dt, J = 15.4, 4.4 Hz, 1H), 1.06–0.94 (m, 1H), 0.88 (d, J = 7.1 Hz, 3H), 0.67 (t, J = 7.6 Hz, 3H), 0.52 (br s, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): (major) δ 151.93, 128.52, 126.81, 125.46, 76.32, 45.60, 39.41, 39.15, 36.23, 32.82, 27.42, 25.82, 25.75, 16.92, 7.30; (minor) δ 151.96, 128.44, 127.02, 125.45, 74.73, 45.39, 37.86, 37.48, 36.81, 35.94, 29.59, 27.27, 22.98, 18.85, 8.82. IR (CCl_4): 3612, 3041, 2928 cm^{-1}. HRMS: calcd for $C_{17}H_{26}O$ 246.1984, found 246.1992. LRMS (EI) *m/e*: (major) 246 (2), 228 (20), 199 (15), 161 (100), 117 (42), 104 (69), 91 (80); (minor) 246 (8), 228 (17), 199 (23), 161 (100), 117 (37), 104 (63), 91 (86). Anal. Calcd for $C_{17}H_{26}O$: C, 82.87; H, 10.64. Found: C, 82.84; H, 10.81.

3-Phenylbicyclo[6.3.0]undecan-1-ol (4h). (**3h**, 0.230 g, 0.95 mmol) isolated 0.092 g (40%) of the (1*R**,5*S**,10*S**) isomer (high R_f) and 0.087 g (38%) of the (1*R**,5*R**,10*S**) isomer (low R_f).

(1*R,3*R**,8*R**)-3-Phenylbicyclo[6.3.0]undecan-1-ol.** ^1H NMR (400 MHz, $CDCl_3$): δ 7.27–7.11 (m, 5H), 3.24–3.19 (m, 1H), 2.04 (dd, J = 14.6, 1.1 Hz, 1H), 1.92 (dd, J = 14.6, 8.6 Hz, 1H), 1.91–1.48 (m, 15H), 1.04 (br s, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 151.65, 128.43, 126.87, 125.43, 79.72, 46.48, 46.01, 43.89, 38.23, 37.81, 33.59, 26.79, 25.47, 24.08, 19.92. IR (CCl_4): 3605, 3471, 3062, 3026, 2921, 2864 cm^{-1}. LRMS (EI) *m/e*: 244 (1), 226 (63), 144 (100), 104 (35), 91 (70). Anal. Calcd for $C_{12}H_{24}O$: C, 83.55; H, 9.90. Found: C, 83.55; H, 9.98.

(1*R,3*R**,8*S**)-3-Phenylbicyclo[6.3.0]undecan-1-ol.** ^1H NMR (400 MHz, $CDCl_3$): δ 7.36–7.18 (m, 5H), 3.24–3.15 (m, 1H), 2.32–2.22 (m, 1H), 2.20 (dd, J = 14.6, 11.0 Hz, 1H), 2.01–1.86 (m, 2H), 1.92 (dd, J = 14.6, 2.7 Hz, 1H), 1.82–1.28 (m, 12H), 1.18 (br s, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 149.38, 128.26, 127.17, 125.53, 83.77, 48.78, 43.09, 41.44, 39.68, 36.24, 33.91, 33.07, 30.00, 23.31, 21.16. IR (CCl_4): 3605, 3026, 2928, 2857 cm^{-1}. LRMS (EI) *m/e*: 244 (1), 226 (63), 144 (100), 104 (35), 91 (70). Anal. Calcd for $C_{12}H_{24}O$: C, 83.55; H, 9.90. Found: C, 83.71; H, 10.32.

3-Phenylbicyclo[5.3.1]undecan-1-ol (4i). (**3i**, 0.290 g, 1.20 mmol) yield 0.230 g (78%) as a 6:1 mixture of diastereomers (separable). ^1H NMR (400 MHz, $CDCl_3$): (major) δ 7.33–7.27 (m, 2H), 7.18–7.16 (m, 2H), 7.12 (tt, J = 7.2, 1.3 Hz, 1H), 2.92–2.85 (m, 1H), 2.29 (dd, J = 15.4, 8.0 Hz, 1H), 2.26 (dd, J = 15.4, 2.2 Hz, 1H), 2.01–1.39 (m, 14H), 1.32 (ddd, J = 13.5, 4.6, 1.7 Hz, 1H), 1.12 (br s, 1H); (minor) δ 7.42–7.41 (m, 2H), 7.30–7.26 (m, 2H), 7.16 (t, J = 7.4 Hz, 1H), 3.42 (pent, J = 5 Hz, 1H), 2.30–2.24 (m, 3H), 2.10–2.06 (m, 1H), 1.96–1.19 (m, 14H). ^{13}C NMR (75 MHz, $CDCl_3$): (major) δ 151.23, 128.45, 126.76, 125.50, 72.02, 47.13, 41.35, 41.14, 40.52, 36.37, 32.52, 29.95, 29.55, 24.94, 19.77. IR (CCl_4): 3420, 2935 cm^{-1}. LRMS (EI) *m/e*: 244 (4), 226 (29), 183 (100), 91 (46). Anal. Calcd for $C_{17}H_{24}O$: C, 83.55; H, 9.90. Found: C, 83.59; H, 9.81.

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Supplementary Material Available: ^1H and ^{13}C NMR spectra of compounds for which no elemental analysis was obtained (66 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.