

Synthesis of Aromatic Compounds Using Combinations of Ring-Closing Olefin Metathesis, Dehydration, Oxidation, and Tautomerization

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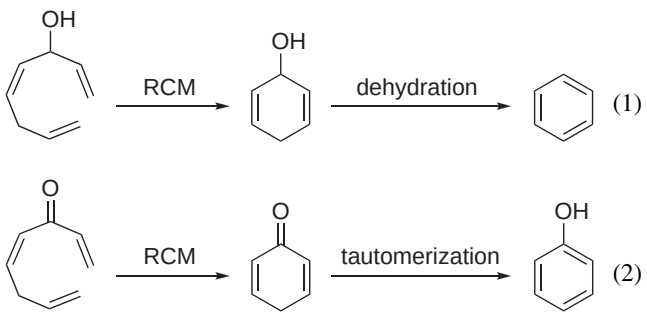
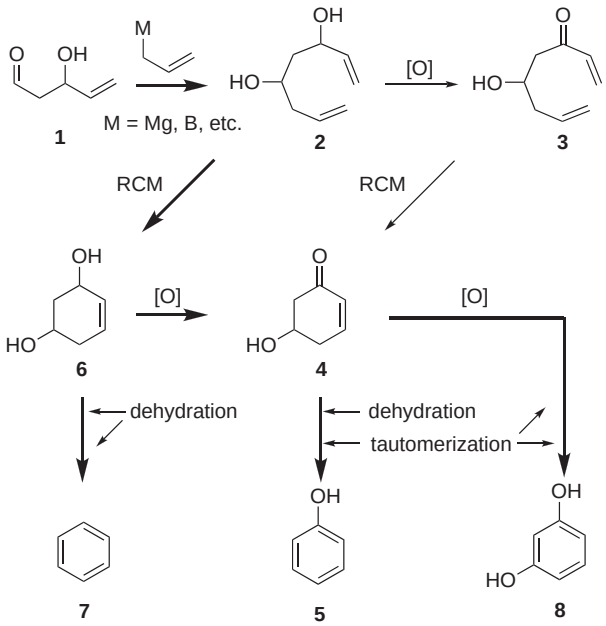
An approach to aromatic compounds using combinations of ring-closing olefin metathesis (RCM), dehydration, oxidation, and tautomerization is reported. The RCM reaction of 1,7-diene-3,5-diols, which were readily prepared by the allylation of aldol products, gave corresponding cyclized products, 4-cyclohexene-1,3-diols, in high yields. The subsequent dehydration or oxidation of 4-cyclohexene-1,3-diols led to versatile substituted benzenes including phenol and resorcinol derivatives.

One important aspect of modern organic chemistry is the development of highly regioselective methods for the synthesis of substituted aromatic compounds.[1] Electrophilic aromatic substitution is considered to be one of the most powerful and general methods for the synthesis of aromatic compounds in industry as well as in the laboratory. However, one weak point of this method is its lack of regioselectivity. Unless there is structural bias, the synthesis often gives a mixture of regioisomers. One possible solution to this problem is the direct construction of aromatic rings from acyclic precursors.[2] Although the preparation of acyclic precursors usually requires several steps, this approach has an advantage to enable perfect regioselective access to the desired aromatic compounds. Recently, the construction of aromatic rings using ring-closing olefin metathesis (RCM)[3,4] has emerged as an interesting and efficient method in this field.[5–7] We also have reported that RCM/dehydration and RCM/tautomerization are valuable processes for the synthesis of benzene and phenol derivatives (eqs 1 and 2).[8] However, from a practical viewpoint, these processes have a limitation: the selective construction of an internal cis double bond is required to obtain the acyclic precursors.



Very recently, we proposed a facile and improved route to phenol derivatives, as outlined in one part of Scheme 1 (route **1**–**2**–**3**–**4**–**5**).[9] In this strategy, phenol derivatives **5** were synthesized by sequential dehydration and tautomerization of key intermediates **4**, after cyclization of 5-hydroxy-1,7-octadien-3-ones **3** that were easily prepared from aldol products **1**. Because the double bond constructed by the dehydration of **4** has cis configuration, this strategy makes it possible to avoid the requirement of selective synthesis of the internal cis double bond of the acyclic precursors. In the present paper, we report further improvement of this methodology. The main improvement is that the cyclization can now be conducted under mild conditions since 1,7-diene-3,5-diol **2** was chosen as the reactive precursor in preference to **3**. First, we describe the cyclization of **2** (route **2**–**6**). Then, we discuss the conversion of **6** into phenol (route **6**–**4**–**5**), benzene (route **6**–**7**), and resorcinol (route **6**–**4**–**8**).



Scheme 1.

Results and Discussion

Electron-deficient dienic systems are known to be weakly reactive in RCM reactions.[10] In this regard, high reaction temperatures (40 to 100 °C) were required to achieve complete conversion in most of the RCM reactions of **3** into **4** in our previous study.[9] Therefore, we started this investigation with the

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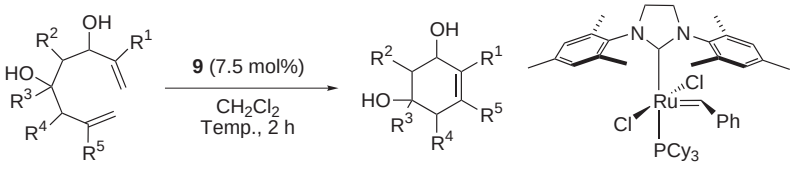
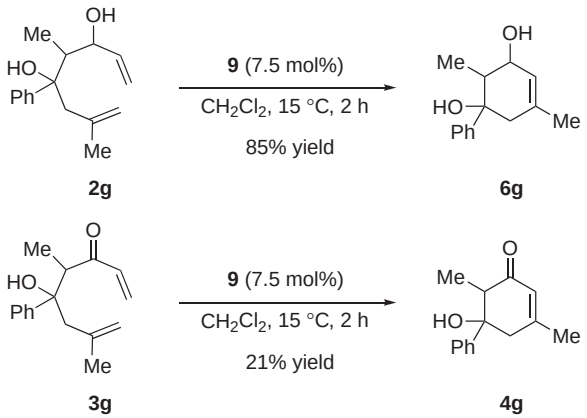
Table 1. Synthesis of 4-Cyclohexene-1,3-diols **6** by Ruthenium-Catalyzed Ring-Closing Olefin Metathesis[a)]



2 **6** **9**

Entry	Substrate	R^1	R^2	R^3	R^4	R^5	Temp.	Yield[b)]/%
1	**2a**	H	Me	Et	H	H	rt	90 (**6a**)
2	**2b**	Me	H	H	Me	H	rt	80 (**6b**)
3	**2c**	Me	H	4-ClC_6H_4	H	H	rt	82 (**6c**)
4	**2d**	$CH_2OSiMe_2{}^tBu$	H	Me	H	H	rt	>99 (**6d**)
5	**2e**	H	H	Ph	H	Me	rt	86 (**6e**)[c)]
6	**2f**	H	H	H	H	CH_2OBn	40 °C	54 (**6f**)

a) Reactions were carried out with 1,7-diene-3,5-diol **2** and ruthenium catalyst **9** (7.5 mol %) in CH_2Cl_2 for 2 h. b) Isolated yield by silica gel chromatography. c) When the amount of catalyst **9** was decreased to 2.5 mol %, the isolated yield of **6e** was decreased to 40%.



Scheme 2.

RCM reaction of **2**, which does not have electron-deficient alkene moieties. The route including cyclization of **2**, followed by oxidation of **6**, seemed to be the most practical.

The results of the RCM reaction of **2** are listed in Table 1. In most cases, the RCM of **2** with Grubbs' second-generation catalyst **9**[11] proceeded well to afford cyclized products **6**. Irrespective of the formation of disubstituted or trisubstituted double bond, the RCM reaction was completed in 2 h at room temperature. An exception was found with substrate **2f** having a benzyloxymethyl group as the R^5 substituent, which was cyclized at high temperature (40 °C) into **6f** in moderate yield (54%). This result is ascribed to the competitive isomerization of the allylic olefin of **2f** to produce a significant amount of the by-product, 7-benzyloxymethyl-5-hydroxy-7-octen-3-one.[12]

The RCM reaction of **2g** was compared with that of **3g** under the same conditions (15 °C, 2 h) to determine the difference in reactivities between **2** and **3** (Scheme 2). As a result, incomplete conversion in the reaction of **3g** gave corresponding cyclic product **4g** only in 21% yield as predicted, whereas a high yield (85%) of **6g** was obtained from **2g**.

We next examined the conversion of **6** into phenol derivatives **5**. Table 2 summarizes the results of the partial oxidation of **6** at allylic alcohol position and the dehydration of **4** to form **5**. Several oxidizing agents, such as Dess–Martin periodinane, MnO_2, or PCC, could be used for the oxidation of **6**. The reactions proceeded well in most cases, but only the best results are selected for entry in Table 2.[13] For the following dehydration, we employed a catalytic amount of *p*-toluenesulfonic acid as Brønsted acid catalyst, and phenol derivatives **5** were obtained in high yields. In the case of **4d** that has an acid-sensitive silyl ether, basic conditions (mesylation of the hydroxy group with *t*-BuOK, followed by elimination) were required to retain the silyl group (Table 2, Entry 4).[14]

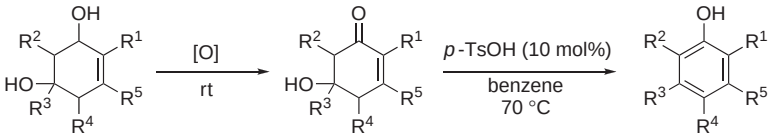
It is possible to perform the conversion of **2** into **4** sequentially without the isolation of **6**. As shown in Scheme 3, RCM reactions of **2h** and **2i**, followed by sequential oxidation with PCC, gave good yields of **4h** and **4i**, respectively.[15] Treatment of **4h** with *p*-toluenesulfonic acid led to aromatization to give corresponding phenol **5h** quantitatively. On the other hand, the same process for **4i** resulted in isomerization of the carbon–carbon double bond from terminal to internal at R^3 position. Therefore, basic conditions (*t*-BuOK, MsCl) were applied to **4i** to obtain **5i**.

4-Cyclohexene-1,3-diols **6** are promising intermediates because the sequential dehydrations process of **6** affords benzene derivatives **7** and the sequential oxidations process of **6** at the two hydroxy groups affords resorcinol derivatives **8**, as outlined in one part of Scheme 1. In fact, the dehydration of **6** with *p*-toluenesulfonic acid proceeded smoothly to give corresponding benzene derivatives **7** (Table 3). Moreover, it was also proved that a combination of Dess–Martin and Swern oxidations of **6f** afforded resorcinol derivative **8f** via **4f** (Scheme 4).[16,17]

Conclusion

We have presented an efficient method for the production of aromatic compounds from acyclic precursors. The key step was the RCM reaction of **2** to form **6**. The choice of **2** as the precursor, instead of less reactive intermediate **3** having electron-deficient olefin, rendered the RCM reaction conditions milder. The formation of a variety of products (benzene, phenol, and resorcinol), which is attributed to the diversity of the transformations of **6**, and no formation of inseparable regioisomers are proof of the versatility of this method for the synthesis of aromatic compounds.

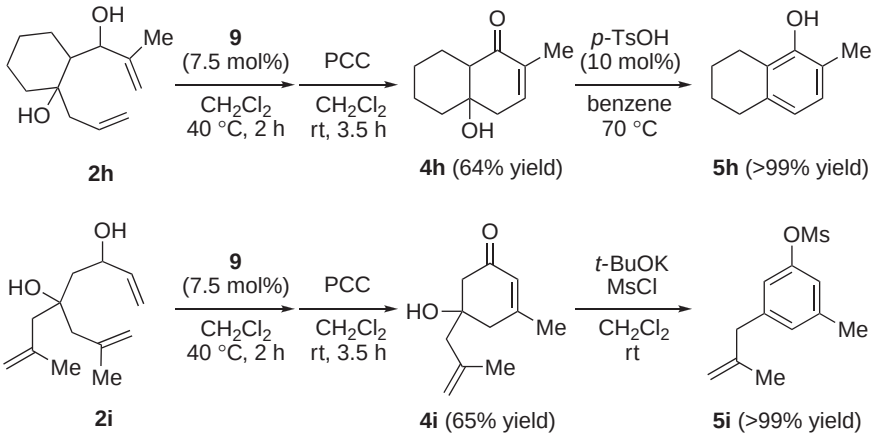
Table 2. Synthesis of 5-Hydroxy-2-cyclohexenones **4** by Oxidation of **6**[a] and Synthesis of Phenol Derivatives **5** by Dehydration of **4**[b]



6 **4** **5**

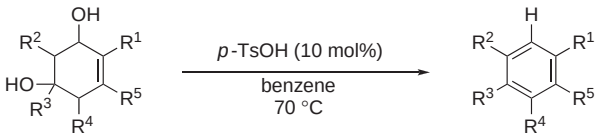
Entry	Substrate	R^1	R^2	R^3	R^4	R^5	Oxidant	Yield[c]/%	Yield[c]/%
1	**6a**	H	Me	Et	H	H	DMP	98 (**4a**)	85 (**5a**)
2	**6b**	Me	H	H	Me	H	MnO_2	86 (**4b**)	>99 (**5b**)
3	**6c**	Me	H	4-ClC_6H_4	H	H	PCC	84 (**4c**)	>99 (**5c**)
4	**6d**	$CH_2OSiMe_2{}^tBu$	H	Me	H	H	PCC	86 (**4d**)	88 (**5d**)[d]
5	**6e**	H	H	Ph	H	Me	DMP	93 (**4e**)	>99 (**5e**)
6	**6f**	H	H	H	H	CH_2OBn	DMP	85 (**4f**)	90 (**5f**)
7	**6g**	H	Me	Ph	H	Me	PCC	97 (**4g**)	97 (**5g**)

a) 4-Cyclohexene-3,5-diol **6** was treated with Dess–Martin periodinane (2.3 equiv), MnO_2 (30 equiv), or PCC (3 equiv). b) A solution of 5-hydroxy-2-cyclohexenone **4** in benzene was treated with *p*-toluenesulfonic acid (*p*-TsOH; 10 mol %) and stirred overnight at 70 °C. c) Isolated yield by silica gel chromatography. d) The reaction was carried out with 5-hydroxy-2-cyclohexenone **4**, *t*-BuOK (4.4 equiv), and MsCl (3.2 equiv) in CH_2Cl_2 at rt for 2.5 h.



Scheme 3.

Table 3. Synthesis of Benzene Derivatives **7** by Dehydration of **6**[a]



6 **7**

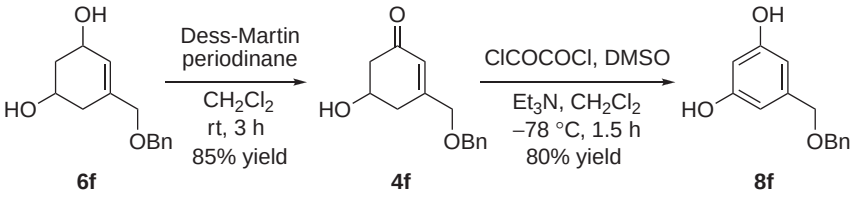
Entry	Substrate	R^1	R^2	R^3	R^4	R^5	Yield[b]/%
1	**6c**	Me	H	4-ClC_6H_4	H	H	>99 (**7c**)
2	**6d**	$CH_2OSiMe_2{}^tBu$	H	Me	H	H	73 (**7d**)[c]
3	**6e**	H	H	Ph	H	Me	91 (**7e**)
4	**6g**	H	Me	Ph	H	Me	>99 (**7g**)

a) A solution of 4-cyclohexene-1,3-diol **6** in benzene was treated with *p*-toluenesulfonic acid (*p*-TsOH; 10 mol %) and stirred overnight at 70 °C. b) Isolated yield by silica gel chromatography. c) Desilylated product.

Experimental

General. All anaerobic and moisture-sensitive manipulations were carried out with standard Schlenk techniques under predried nitrogen or glove box techniques under prepurified argon. NMR spectra were recorded on a JEOL JNM LA-500 spectrometer (500 MHz for ^1H and 125 MHz for ^{13}C) and LA-400 spectrometer (400 MHz for ^1H and 100 MHz for ^{13}C). Chemical shifts are reported in δ referenced to an internal $SiMe_4$ standard for ^1H NMR and chloroform-*d* (δ 77.0) for ^{13}C NMR.

Materials. THF was distilled from sodium benzophenone-ketyl under argon prior to use. Et_2O was distilled from sodium benzophenone-ketyl under argon prior to use. Dichloromethane was distilled from CaH_2 under nitrogen and stored in a glass



Scheme 4.

flask with a Teflon stopcock under nitrogen. Ruthenium complex $(PCy_3)(Imes)Cl_2Ru{=}C(H)Ph$ (**9**) was prepared according to reported procedures.[11b] 1,7-Octadiene-3,5-diols **2** were prepared according to reported procedures.[9] Dess–Martin periodinane,[18] and activated MnO_2[19] were prepared according to reported procedures. Pyridinium chlorochromate, *p*-toluenesulfonic acid were used as received.

Preparation of 4-Cyclohexene-1,3-diols 6. General Procedure A: To a solution of 1,7-octadiene-3,5-diol **2** (0.16 mmol) in CH_2Cl_2 (15.5 mL, 0.01 M) was added 7.5 mol % catalyst **9** (0.012 mmol) in one portion under nitrogen at room temperature. After stirring for 2 h, the reaction mixture was concentrated under reduced pressure and purified by PTLC on silica gel to give 4-cyclohexene-1,3-diols **6**.

1-Ethyl-2-methyl-4-cyclohexene-1,3-diol (6a): The reaction was carried out according to General Procedure A; purified by PTLC (hexane/EtOAc = 1/1) (diastereomeric mixture: 90% yield); Two of the diastereomers (0.50/0.50) were separated to clarify the spectral characterization. ^{1}H NMR ($CDCl_3$): δ 0.83 (d, J = 6.8 Hz, 1.5H), 0.90 (t, J = 7.6 Hz, 1.5H), 0.94 (t, J = 7.6 Hz, 1.5H), 1.10 (d, J = 6.8 Hz, 1.5H), 1.42 (br s, 1.0H), 1.50–1.60 (m, 3.0H), 1.67 (br s, 1.0H), 1.89–2.16 (m, 1.5H), 2.28 (dq, J = 18.3, 2.5 Hz, 0.5H), 3.97–4.03 (m, 0.5H), 4.63–4.69 (br m, 0.5H), 5.59–5.79 (m, 2.0H). ^{13}C NMR ($CDCl_3$): δ 6.45, 8.02, 9.13, 10.56, 32.29, 32.57, 35.07, 36.40, 41.04, 43.44, 68.33, 71.78, 74.26, 75.10, 125.27, 125.65, 129.51, 130.46. HRMS (FAB) calcd for $C_9H_{15}O$ ($M^+ - OH$) 139.1123, found 139.1120.

4,6-Dimethyl-4-cyclohexene-1,3-diol (6b): The reaction was carried out according to General Procedure A; purified by PTLC (hexane/EtOAc = 1/1) (diastereomeric mixture: 80% yield); The following data are for a mixture of two diastereomers (0.50/0.50). ^{1}H NMR ($CDCl_3$): δ 0.98 (d, J = 7.3 Hz, 1.5H), 1.11 (d, J = 7.1 Hz, 1.5H), 1.70–1.83 (m, 3.0H), 1.78 (s, 3.0H), 2.00–2.15 (m, 1.5H), 2.41 (br m, 0.5H), 3.55–3.62 (m, 0.5H), 4.08–4.13 (m, 1.0H), 4.18–4.22 (m, 0.5H), 5.26–5.28 (m, 0.5H), 5.32–5.35 (m, 0.5H). ^{13}C NMR ($CDCl_3$): δ 14.70, 18.51, 20.24, 20.56, 35.50, 37.70, 39.67, 40.53, 67.98, 68.90, 69.68, 70.33, 128.86, 129.90, 134.25, 134.60. HRMS (FAB) calcd for $C_8H_{13}O$ ($M^+ - OH$) 125.0966, found 125.0967.

1-(4-Chlorophenyl)-4-methyl-4-cyclohexene-1,3-diol (6c): The synthesis of **6c** was already reported in our previous communication.[9]

4-(*tert*-Butyldimethylsilanyloxymethyl)-1-methyl-4-cyclohexene-1,3-diol (6d): The reaction was carried out according to General Procedure A; purified by PTLC (hexane/EtOAc = 1/1) (diastereomeric mixture: >99% yield); The following data are for a mixture of two diastereomers (0.75/0.25). ^{1}H NMR ($CDCl_3$): δ 0.10–0.11 (m, 6.0H), 0.91 (s, 2.25H), 0.91 (s, 6.75H), 1.29 (s, 0.75H), 1.34 (s, 2.25H), 1.68 (dd, J = 13.2, 8.1 Hz, 1.5H), 1.70–1.73 (m, 0.5H), 2.05–2.15 (m, 2.0H), 2.21–2.35 (m, 1.0H), 3.28–3.32 (m, 0.75H), 3.66–3.68 (m, 0.25H), 3.93–3.96 (m, 0.25H), 4.20–4.38 (m, 2.0H), 4.54–4.60 (m, 0.75H), 5.58–5.63 (m, 0.75H), 5.68–5.73 (m, 0.25H). ^{13}C NMR ($CDCl_3$): δ −5.50, −5.48, −5.44, −5.42, 18.16, 18.20, 25.82, 29.88, 29.98, 39.52, 39.83, 40.80, 44.26, 66.71, 66.81, 67.47, 67.63, 68.38, 69.91, 122.67, 123.88, 136.25, 137.33. HRMS (FAB) calcd for $C_{14}H_{27}O_2Si$ ($M^+ - OH$) 255.1780, found 255.1788.

5-Methyl-1-phenyl-4-cyclohexene-1,3-diol (6e): The reaction was carried out according to General Procedure A; purified by PTLC (hexane/EtOAc = 1/1) (86% yield); One of the diastereomers of **2e** was used for this reaction. ^{1}H NMR ($CDCl_3$): δ 1.46 (d, J = 5.5 Hz, 1H), 1.77 (s, 3H), 1.85 (s, 1H), 1.99 (dd, J = 12.9, 8.9 Hz, 1H), 2.19 (d, J = 18.2 Hz, 1H), 2.34 (dd, J = 13.0, 6.2 Hz, 1H), 2.51 (d, J = 18.2 Hz, 1H), 4.55–4.65 (m, 1H), 5.62 (s, 1H), 7.29 (t, J = 7.1 Hz, 1H), 7.38 (t, J = 8.0 Hz, 2H), 7.50 (d, J = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$): δ 23.12, 43.60, 44.84, 66.71, 74.02, 124.43, 124.83, 127.23, 128.44, 134.01, 147.39. HRMS (FAB) calcd for $C_{13}H_{15}O$ ($M^+ - OH$) 187.1123, found 187.1118.

5-Benzyloxymethyl-4-cyclohexene-1,3-diol (6f): The reaction was carried out according to General Procedure A; purified by PTLC (hexane/EtOAc = 1/4) (diastereomeric mixture: 54% yield); The following data are for a mixture of two diastereomers (0.50/0.50). ^{1}H NMR ($CDCl_3$): δ 1.78–1.82 (m, 0.5H), 1.93–2.07 (m, 1.5H), 2.15–2.43 (m, 2.5H), 2.52 (dd, J = 16.4, 8.6 Hz, 0.5H), 2.62 (dd, J = 17.6, 4.2 Hz, 0.5H), 2.73 (dd, J = 16.1, 3.4 Hz, 0.5H), 3.96 (s, 1.0H), 4.12 (s, 1.0H), 4.23–4.37 (m, 2.0H), 4.51 (s, 1.0H), 4.57 (s, 1.0H), 5.92–5.95 (m, 0.5H), 6.21–6.23 (m, 0.5H), 7.28–7.40 (m, 5.0H). ^{13}C NMR ($CDCl_3$): δ 34.72, 35.07, 37.62, 39.73, 64.00, 64.80, 65.01, 65.47, 72.14, 72.28, 73.37, 73.66, 125.37, 126.14, 127.67, 127.72, 127.76, 127.83, 128.37, 128.45, 134.19, 136.08, 137.98, 137.99. HRMS (FAB) calcd for $C_{14}H_{17}O_2$ ($M^+ - OH$) 217.1229, found 217.1230.

2,5-Dimethyl-1-phenyl-4-cyclohexene-1,3-diol (6g): The reaction was carried out according to General Procedure A; purified by PTLC (hexane/EtOAc = 1/1) (diastereomeric mixture: >99% yield); One of the diastereomers was separated to clarify the spectral characterization. ^{1}H NMR ($CDCl_3$): δ 0.84 (d, J = 6.8 Hz, 3H), 1.56 (br s, 1H), 1.73 (s, 3H), 1.85 (s, 1H), 2.01 (dq, J = 8.6, 6.8 Hz, 1H), 2.12 (d, J = 18.2 Hz, 1H), 2.61 (d, J = 18.2 Hz, 1H), 4.07–4.14 (m, 1H), 5.59 (s, 1H), 7.25 (tt, J = 7.4, 1.6 Hz, 1H), 7.36 (dd, J = 8.3, 7.4 Hz, 2H), 7.43 (dd, J = 8.3, 1.6 Hz, 2H). ^{13}C NMR ($CDCl_3$): δ 11.69, 22.96, 44.76, 46.93, 72.50, 76.82, 124.64, 124.84, 126.65, 128.29, 133.73, 146.03. HRMS (FAB) calcd for $C_{14}H_{17}O$ ($M^+ - OH$) 201.1279, found 201.1269.

Preparation of 5-Hydroxy-2-cyclohexenones 4. General Procedure B: To a solution of **6** (0.0588 mmol) in CH_2Cl_2 (1.1 mL) was added Dess–Martin periodinane (0.135 mmol) in one portion under air. The reaction mixture was stirred for 3 h at room temperature. After removal of the solvent in vacuo, the residue was passed through a short silica gel pad (eluent: Et_2O). The solution was concentrated under reduced pressure and purified by PTLC on silica gel to give 5-hydroxy-2-cyclohexenone **4**.

General Procedure C: To a solution of **6** (0.136 mmol) in hexane (5.0 mL) was added MnO_2 (4.07 mmol) in one portion under air. The reaction mixture was stirred for 37 h at room temperature and passed through Celite. The residue was washed with CH_2Cl_2 thoroughly. The filtrate was concentrated under reduced pressure and purified by PTLC on silica gel to give 5-hydroxy-2-cyclohexenone **4**.

General Procedure D: To a mixture of **6** (0.128 mmol) and molecular sieve 4 Å (powder, 135 mg) in CH_2Cl_2 (4.0 mL) was added PCC (0.383 mmol) under air. After stirring for 3.5 h at room temperature, the reaction mixture was filtered through Celite, concentrated under reduced pressure, and purified by PTLC on silica gel to give 5-hydroxy-2-cyclohexenone **4**.

General Procedure E: To a solution of 1,7-octadiene-3,5-diol **2** (0.169 mmol) in CH_2Cl_2 (16.9 mL) was added 7.5 mol % catalyst **9** (0.0127 mmol) in one portion under nitrogen at room temperature. After stirring for 2 h, the reaction mixture was concentrated under reduced pressure. To a mixture of the residue and molecular sieve 4 Å (powder, 178.5 mg) in CH_2Cl_2 (5.0 mL) was added PCC (0.506 mmol). After stirring for 3.5 h, the reaction mixture was filtered through Celite, concentrated under reduced pressure, and purified by PTLC on silica gel to give 5-hydroxy-2-cyclohexenone **4**.

5-Ethyl-5-hydroxy-6-methyl-2-cyclohexenone (4a): The reaction was carried out according to General Procedure B and purified by PTLC (hexane/EtOAc = 1/1) (98% yield); This product was characterized by comparison of the spectroscopic data with those reported previously.[9]

5-Hydroxy-2,4-dimethyl-2-cyclohexenone (4b): The reaction was carried out according to General Procedure C and purified by PTLC (hexane/EtOAc = 1/1) (86% yield); This product was characterized by comparison of the spectroscopic data with those reported previously.[9]

5-(4-Chlorophenyl)-5-hydroxy-2-methyl-2-cyclohexenone (4c): The reaction was carried out according to General Procedure D and purified by PTLC (hexane/EtOAc = 1/1) (84% yield); This product was characterized by comparison of the spectroscopic data with those reported previously.[9]

2-(*tert*-Butyldimethylsilanyloxymethyl)-5-hydroxy-5-methyl-2-cyclohexenone (4d): The reaction was carried out according to General Procedure D and purified by PTLC (hexane/EtOAc = 1/1) (86% yield); This product was characterized by comparison of the spectroscopic data with those reported previously.[9]

5-Hydroxy-3-methyl-5-phenyl-2-cyclohexenone (4e): The reaction was carried out according to General Procedure B and purified by PTLC (hexane/EtOAc = 1/2) (93% yield); This product was characterized by comparison of the spectroscopic data with those reported previously.[9]

3-Benzyloxymethyl-5-hydroxy-2-cyclohexenone (4f): The reaction was carried out according to General Procedure B and purified by PTLC (hexane/EtOAc = 1/1) (85% yield); This product was characterized by comparison of the spectroscopic data with those reported previously.[9]

5-Hydroxy-3,6-dimethyl-5-phenyl-2-cyclohexenone (4g): The reaction was carried out according to General Procedure D and purified by PTLC (hexane/EtOAc = 1/1) (97% yield); This product was characterized by comparison of the spectroscopic data with those reported previously.[9]

6-Hydroxy-3-methylbicyclo[4,4,0]-3-decen-2-one (4h): The reaction was carried out according to General Procedure E and purified by PTLC (hexane/EtOAc = 1/1) (64% yield); This product was characterized by comparison of the spectroscopic data with those reported previously.[9]

5-Hydroxy-3-methyl-5-(2-methylallyl)-2-cyclohexenone (4i): The reaction was carried out according to General Procedure E and purified by PTLC (hexane/EtOAc = 1/1) (65% yield); This product was characterized by comparison of the spectroscopic data with those reported previously.[9]

Preparation of Phenol Derivatives 5. The synthesis of **5** from **4** was already reported in our previous communication.[9]

Preparation of Benzene Derivatives 7. General Procedure F: To a solution of 4-cyclohexene-1,3-diol **6** (0.0558 mmol) in benzene (1.0 mL) was added *p*-toluenesulfonic acid (0.00558 mmol) at room temperature under air. The reaction mixture was warmed to 70 °C and stirred overnight. The resulting mixture was concentrated under reduced pressure and purified by PTLC on silica gel to give benzene derivative **7**.

4-Chloro-4′-methylbiphenyl (7c): The reaction was carried out according to General Procedure F and purified by PTLC (hexane/EtOAc = 4/1) (>99% yield); This product was characterized by comparison of the spectroscopic data with those reported previously.[20]

***p*-Tolylmethanol (7d):** The reaction was carried out according to General Procedure F and purified by PTLC (hexane/EtOAc = 10/1) (73% yield); This product was characterized by comparison of the spectroscopic data with those reported previously.[21]

3-Methylbiphenyl (7e): The reaction was carried out according to General Procedure F and purified by PTLC (hexane only) (91% yield); This product was characterized by comparison of the spectroscopic data with those reported previously.[22]

2,5-Dimethylbiphenyl (7g): The reaction was carried out according to General Procedure F and purified by PTLC (hexane only) (86% yield); This product was characterized by comparison of the spectroscopic data with those reported previously.[23]

Preparation of 5-Benzyloxymethyl-1,3-benzenediol (8f). The synthesis of **8f** from **4f** was already reported in our previous communication.[9]

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Supporting Information

^{1}H NMR and ^{13}C NMR spectra of new compounds, and ^{1}H NMR spectra of known compounds. This material is available free of charge on the Web at: http://www.csj.jp/journals/bcsj/.

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15 The reason why we chose **2h** and **2i** as substrates to investigate these sequential experiments is that we observed that both intermediates **6h** and **6i** were somewhat unstable to isolation.

16 Attempts to obtain **8f** from **6f** at once were unsuccessful. For example, Swern oxidation of **6f** gave a mixture of **4f**, **5f** (major), and **8f**.

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