Preparation of 2,4,5-Triarylimidazol-4-ols and Their Stereoselective Rearrangement by 1,5-Phenyl Migration

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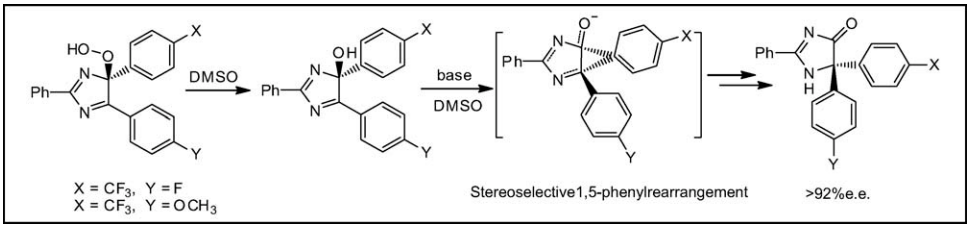

Lophine hydroperoxides underwent base-triggered 1,5-phenyl migration in DMSO to afford imidazolones in high yields, instead of amidines with chemiluminescence (CL). The corresponding imidazolols were believed to intermediates and they were successfully obtained by treating the peroxides with DMSO without the base. The diminished CL was because of the reduction of the hydroperoxides with DMSO. The imidazolols subsequently underwent smooth base-mediated rearrangement to afford imidazolones. Furthermore, the chiral imidazolols provided stereoselective imidazolones in high enantiomeric excess (>92%), which supported the mechanism of an intramolecular ring for the migration.

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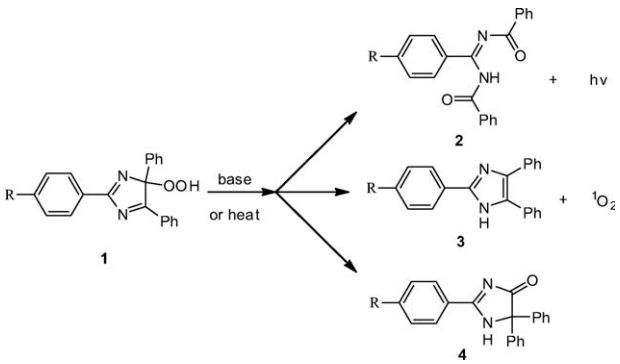
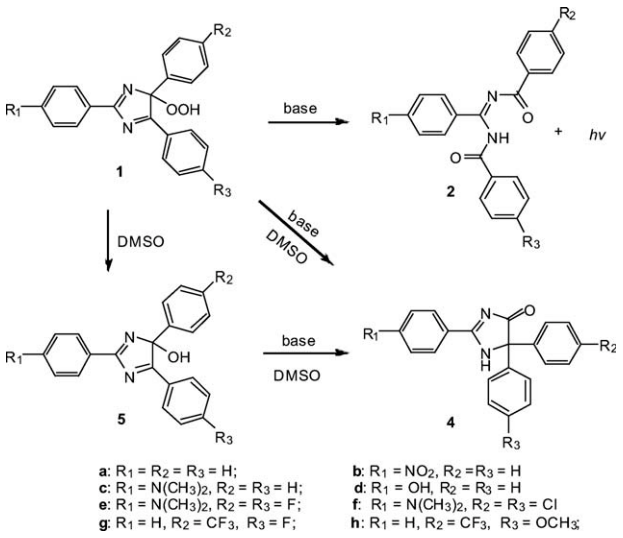
INTRODUCTION

The chemiluminescent reactions of lophine hydroperoxides (**1**) have attracted considerable attention for many decades [1,2]. Many studies have been reported [3] and these studies mainly focused on the chemiluminescence (CL) efficiency. The other reactions occurring in this chemiluminescent process are still not clear. Recently, we reported that **1** underwent three different but simultaneous reactions upon treatment with a base to yield the corresponding amidines (**2**) accompanied with CL, imidazoles (**3**) with singlet oxygen, and a trace of imidazolones (**4**) (Scheme 1) [4]. However, the CL of peroxides **1** can be observed by base-triggered reactions in typical solvents, but not in DMSO. It is well known that a CL system like dioxetane can provide the most efficient CL in DMSO [5]. We first believed that a polar aprotic solvent like DMSO should enhance the CL efficiency of lophine peroxides. However, the CL efficiency of hydroperoxides **1** in was so low that it could not be detected. The results were quite unexpected, and therefore, they attracted our attention. The subsequent investigation showed that hydroperoxides **1** underwent an exclusive 1,5-phenyl migration in DMSO to afford imidazolones **4** in high yields via imidazolols (**5**) as intermediates (Scheme 2) [6]. Further investigation showed that these imidazolols **5** could be easily obtained under milder conditions, when treated with DMSO without the trigger base [6b]. In addition, these imidazolols **5** subsequently underwent base-mediated rearrangement to afford imidazolones in high yields.

Scheme 1



Scheme 2



Although imidazolol has been long proposed as one of the intermediate byproducts in the CL reaction of lophine, it has not been obtained thus far because it is unstable under basic reaction conditions [1b]. The present research provides an easy method to obtain these intermediates, and this should help in completely understanding the reactions occurring in the CL reaction of lophine peroxides. In addition, the sigmatropic migration of an aryl group is known for 1,2,3,4,5-pentaphenylcyclo-pentadienol [7], which is a π-conjugated analogue of **5**; however, its stereochemistry has not yet been investigated. In a previous investigation, [6a] the 1,5-phenyl rearrangement of silyl-protected hydroperoxides was reported. However, the stereospecificities were low under thermal conditions and the enantiomeric excesses (EEs) were less than 60%; these factors made it difficult to understand the stereochemistry. In the previous study, we first believed that the low stereospecificities resulted from the racemization of imidazolones through a ring opening/closing sequence, and therefore, a control experiment was carried out with imidazolone; however, it was found that it did not racemize. Therefore, we believed that the alkoxide racemized through a ring opening/closing sequence under strong thermal conditions that lowered the stereochemical specificities. In this study, the absence of strong thermal activation prevents ring opening from occurring, as a result of which imidazolols can serve as a good system for the study of 1,5-phenyl migration.

Furthermore, it should be noted that many natural compounds include imidazolol and/or imidazolone moieties [8]. In this article, we report the preparation and the stereoselective 1,5-phenyl rearrangement of imidazolols. We expect that imidazolols will find numerous applications in the synthesis of natural compounds.

RESULTS AND DISCUSSION

The reaction of the peroxides **1** proceeded smoothly proceeded to afford imidazolols in good yields in DMSO at room temperature (entries 1–8, Table 1). The reaction completed within 4–6 h. Aromatic substituents containing electron-donating as well as electron-withdrawing groups underwent the elimination of oxygen facilely. In the case of unstable **1c**, which is difficult to isolate, [2] **5c** was consequently prepared by treating the mixture by the photooxidation of the corresponding imidazole with DMSO. In the cases of **1g**, **h**, the mixtures with their isomers (**1′g**, **h**) were used to afford mixtures of **5g**, **h** with their isomers (**5′g**, **h**), as shown in Scheme 3.

On treatment with the base, the imidazolols **5** were smoothly converted into the imidazolones **4** via phenyl migration from C4 to C5 within 3 h in good yields in DMSO at room temperature (Table 1). From the Woodward–Hoffmann rules, the phenyl migration is recognized as a thermally allowed 1,5-sigmatropic migration.

To elucidate the stereochemistry of the migration, imidazolols **5g**, **h** were successfully isolated from their mixtures with their isomers **5′g**, **h** by crystallization from 2-propanol, respectively. The chiral imidazolols (**5g** and **h**) were isolated using a chiral HPLC column. To determine the absolute configurations, the circular dichroism (CD) spectra were recorded, and the calculated CD spectra were processed using Gaussian 03w software package [6a,9]. The absolute configurations were assigned by comparing the experimental CD spectra with the calculated ones (for details, see Experimental section). When the chiral imidazolols (**5g** and **h**)

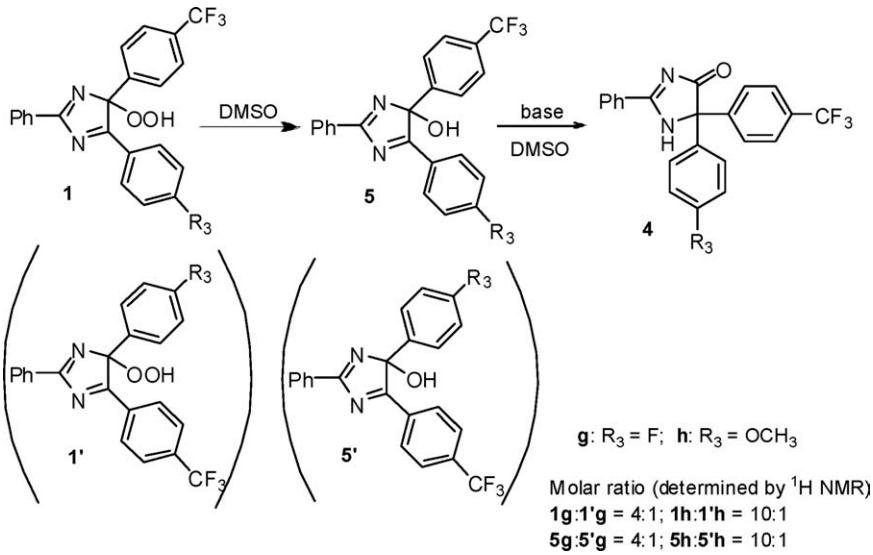
Table 1

Preparation of imidazolols and imidazolones.

Entry	Reactants	Product[a]	Yield (%)[b]
1	**1a**	**5a**	77
2	**1b**	**5b**	87
3	**1c**	**5c**	64
4	**1d**	**5d**	76
5	**1e**	**5e**	70
6	**1f**	**5f**	72
7	**1g**[c]	**5g**[c]	78
8	**1h**[c]	**5h**[c]	82
9	**5a**	**4a**	78
10	**5b**	**4b**	85
11	**5c**	**4c**	68
12	**5d**	**4d**	73
13	**5e**	**4e**	70
14	**5f**	**4f**	76
15	**5g**[c]	**4g**	79
16	**5h**[c]	**4h**	74

[a] The structure of products were determined from spectral data (^{1}H NMR, MS, and E.A.).
[b] Isolated yields after column chromatography.
[c] Mixture with its isomer.

Scheme 3



were subjected to phenyl migration under the action of the base (Scheme 4), the corresponding imidazolones **4g** and **h** were exclusively obtained in >92% EE in DMSO (Table 2). When compared with the previous study in which silyl-protected peroxides under thermal condition were used, the stereoselectivities were largely increased. The reaction mechanism was confirmed to be stereoselective 1,5-phenyl migration via an intramolecular ring (Scheme 5).

In conclusion, we have demonstrated that an imidazolol derivative can easily be prepared in good yield from the corresponding peroxide. The imidazolol can be smoothly converted to an imidazolone via a stereoselective phenyl migration from C4 to C5 under the action of a base.

EXPERIMENTAL

General procedure. All melting points were measured using a Yanagimoto micro melting point apparatus. The IR spectra were recorded by a JASCO FT/IR-5000 spectrophotometer. The UV-vis spectra were measured by a JASCO V-530 spectro-photometer. The ^{1}H and ^{13}C NMR spectra were recorded using a Varian MERCURY (FT, 300 MHz) spectrometer or a Varian VXR-500 (FT, 500 MHz) spectrometer. Elemental analyses were performed by a Perkin Elmer CHNS/O

Scheme 4

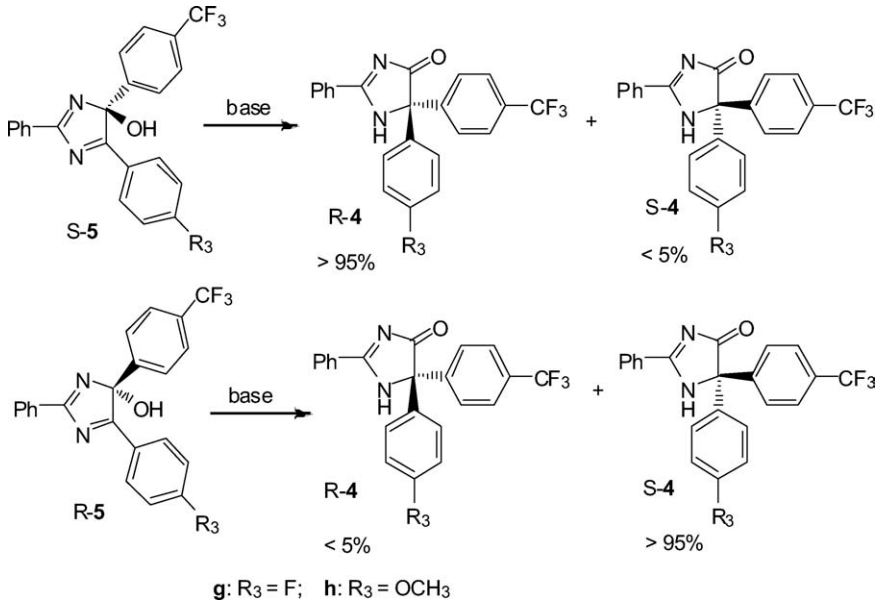


Table 2

The analyses of the enantiomeric excess.

Entry	Imidazolols	Products[a,b]		
		R-4	S-4	EE (%)
1	**R-5g**	2	98	96
2	**S-5g**	97	3	94
3	**R-5h**	3	97	94
4	**S-5h**	96	4	92

[a] Yields calculated on the base of HPLC integral quantity.
[b] The conversion was estimated to be 100% because of no other peak appearing on the ^{1}H NMR spectra.

Analyzer 2400. The fast atom bombardment (FAB) mass spectra were recorded by a Micromass 70-SE. 2,4,5-Triarylphenyl-1*H*-imidazoles were prepared by the method of Davidson *et al*. [6,8a]. 4-Hydroperoxy-2,4,5-triphenyl-4*H*-imidazoles were prepared by the method of White and Harding [2]. HPLC analyses were performed on a Hitachi 655 liquid chromatography and recorded on a Hitachi 561 recorder; Column for EE and optical resolution was Daicel Chiralpak AD-H: 4.6 mm × 250 mm. CD spectra were recorded on a JASCO J-820 spectropolarimeter.

Preparation of imidazolols. A solution of hydroperoxides **1** (0.2 mmol) in DMSO (5 mL) was stirred for 4–6 h at room temperature. After the reaction, the solution was poured into water, and the crude product **5** was obtained by filtration. The crude product was purified by chromatography (silica, hexane:AcOEt = 10 ∼ 8:1).

2,4,5-Triphenyl-4-hydroxy-4H-isoimidazole (5a). mp 128–130°C; IR (KBr) 1613 (C=N) cm^{-1}, ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.16–7.22 (m, 3H), 7.34 (dd, *J* = 7.5, 5.5 Hz, 2H), 7.38 (t, *J* = 7.5 Hz, 2H), 7.47 (t, *J* = 7.5 Hz, 1H), 7.49 (d, *J* = 7.5 Hz, 2H), 7.56 (t, *J* = 7.5 Hz, 1H), 8.16 (d, *J* = 7.5 Hz, 2H), 8.41 (d, *J* = 7.5 Hz, 2H), 6.49 (br s, 1H); ^{13}C NMR (300 MHz, $CDCl_3$) δ 107.66 (s), 124.9 (d), 128.3 (d), 128.6 (d), 128.7 (d), 128.8 (d), 129.8 (d), 130.2 (d), 130.6 (d), 130.9 (s), 132.5 (d), 133.0 (d), 137.6 (s), 172.5 (s), 194.3 (s); UV-vis λ_{max} (EtOH) 281 (log ε 4.31) nm; MS (FAB) *m*/*z* 313 (M^++1); E.A. Calcd for $C_{21}H_{16}N_2O$: C, C, 80.75; H, 5.16; N, 8.97. Found: C, 80.70; H, 5.14; N, 8.96.

2-(p-Nitrophenyl)-4-hydroxy-4,5-diphenyl-4H-isoimidazole (5b.) Pale yellow powder, mp 168–169°C; IR (KBr) 1633 (C=N), 1524 (NO_2), 1350 (NO_2) cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.33–7.38 (m, 3H), 7,43 (dd, *J* = 8.4, 2.0 Hz, 2H), 7.56 (t, *J* = 8.1 Hz, 2H), 7.66 (t, *J* = 8.1 Hz, 1H), 8.09 (d, *J* = 9.2 Hz, 2H), 8.19 (d, *J* = 9.2 Hz, 2H), 8.36 (d, *J* = 8.1 Hz, 2H), 6.94 (s, 1H); MS (FAB) *m*/*z* 358 (M^++1); E.A. Calcd for $C_{21}H_{15}N_3O_3$: C, 70.58; H, 4.23; N, 11.76. Found: C, 70.53; H, 4.30; N, 11.73%.

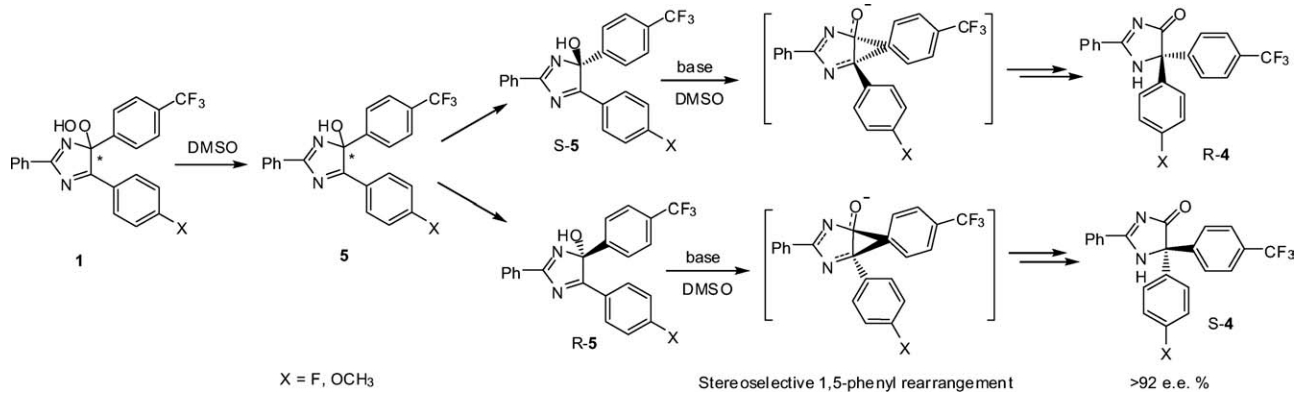
2-(p-Dimethylaminophenyl)-4-hydroxy-4,5-diphenyl-4H-isoimidazole (5c). Orange powder, mp 126–128°C; IR (KBr) 1603 (C=N) cm^{-1}; ^{1}H NMR (500 MHz $CDCl_3$) δ 3.00 (s, 6H), 6.44 (d, *J* = 7.5 Hz, 2H), 7.26–7.31 (m, 3H), 7.47 (dd, *J* = 7.0, 7.53 Hz, 2H), 7.48–7.51 (m, 2H), 7.53 (d, *J* = 7.53 Hz, 1H), 7.93 (d, *J* = 7.5 Hz, 2H), 8.35 (d, *J* = 7.0 Hz, 2H), 6.32 (br s, 1H); MS (FAB) *m*/*z* 356 (M^++1); E.A. Calcd for $C_{23}H_{21}N_3O$: C, 77.72; H, 5.96; N, 11.82. Found: C, 77.77; H, 5.98; N, 11.81.

2-(p-Hydroxyphenyl)-4-hydroxy-4,5-diphenyl-4H-isoimidazole (5d). Yellow powder; mp 103–105°C (dec.); IR (KBr) 3326 (O—H), 1607 (C=N) cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.00–7.03 (m, 2H), 7.30–7.34 (m, 5H), 7.41–7.51 (m, 3H), 7.59 (d, *J* = 7.5 Hz,2H), 8.29 (d, *J* = 7.5 Hz, 2H). MS (FAB) *m*/*z* 329 ($M+H^+$). E.A. Calcd for $C_{21}H_{16}N_2O_2 \cdot 1/2H_2O$: C, 74.76; H, 5.08; N, 8.30. Found: C, 74.69; H, 5.02; N, 8.81.

2-(p-Dimethylaminophenyl)-4-hydroxy-4,5-bis(p-fluorophenyl)4H-isoimidazole (5e). Orange powder; mp 138–140°C (dec.); IR (KBr) 1603 (C=N) cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.04 (s, 6H), 6.64 (d, *J* = 8.9 Hz, 2H), 6.97 (t, *J* = 8.8 Hz, 2H), 7.15 (t, *J* = 9.0 Hz, 2H), 7.40 (d, *J* = 8.8, 2H), 7.98 (d, *J* = 8.9 Hz, 2H), 8.35 (d, *J* = 9.0 Hz, 2H), 6.52 (br s, 1H); E.A. Calcd for $C_{23}H_{19}F_2N_3O$: C, 67.81; H, 4.70; N, 10.31. Found: C, 67.78; H, 4.76; N, 10.31.

2-(p-Dimethylaminophenyl)-4-hydroxy-4,5-bis(p-chlorophenyl)4H-isoimidazole (5f). Orange powder; mp 142–144°C (dec.); IR (KBr) 1601 (C=N) cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.02 (s, 6H), 6.65 (d, *J* = 8.9 Hz, 2H), 6.90 (t, *J* = 8.8 Hz, 2H), 7.12 (t, *J* = 9.0 Hz, 2H), 7.41 (d, *J* = 8.8, 2H), 7.86 (d, *J* = 8.9 Hz, 2H), 8.25 (d, *J* = 9.0 Hz, 2H), 6.49 (br s,

Scheme 5



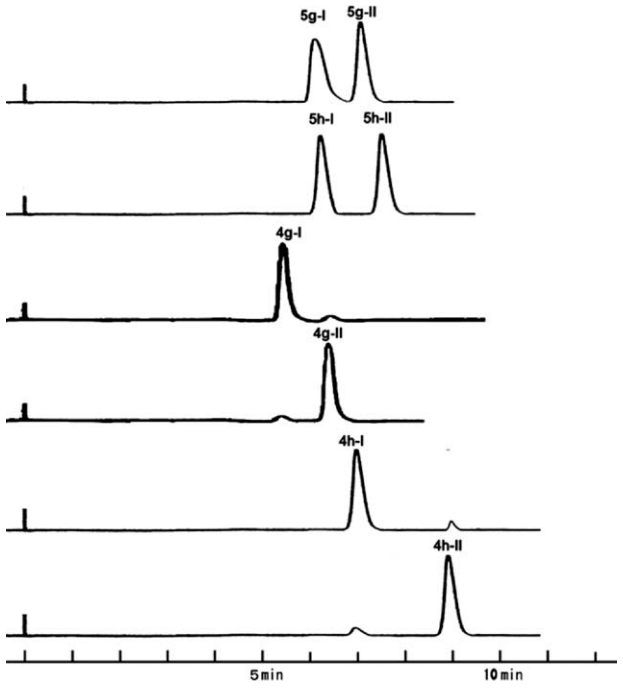


Figure 1. HPLC charts for the resolution.

1H); E.A. Calcd for $C_{23}H_{19}F_2N_3O$: C, 67.81; H, 4.70; N, 10.31. Found: C, 67.35; H, 4.66; N, 10.12.

Mixture of 2-phenyl-4-hydroxy-4-(p-trifluoromethyl-phenyl)-5-(p-fluorophenyl)-4H-isoimidazole (5g) and 2-phenyl-4-hydroxy-4-(p-fluorophenyl)-5-(p-trifluoromethyl-phenyl)-4H-isoimidazole (5′g). Molar ratio = 4:1, determined by ^{1}H NMR. Colorless powder; mp 136–139°C; IR (KBr) 1603 (C=N), 1325 (CF_3), 1272 (C—F) cm^{-1}; UV-vis λ_{max} (CH_2Cl_2) 281 (4.28) nm. MS (FAB) *m/z* 399 (M^++1); E.A. Calcd for $C_{22}H_{14}F_4N_2O{\cdot}1/2H_2O$: C, 64.87; H, 3.71; N, 6.88;. Found: C, 64.83; H, 3.75; N, 6.88%. **5g:** ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.18–7.28 (m, 4H), 7.38–7.44 (m, 1H), 7.55 (d, *J* = 8.5 Hz, 2H), 7.61 (d, *J* = 8.5 Hz, 2H), 7.97 (d, *J* = 7.5 Hz, 2H), 8.33 (dd, *J* = 8.5, 5.5 Hz, 2H); **5′g**: ^{1}H NMR (500 MHz, $CDCl_3$) 7.03 (t, *J* = 8.5 Hz, 2H), 7.18–7.27 (m, 2H), 7.37–7.44 (m, 3H), 7.78 (d, *J* = 8.2 Hz, 2H), 7.95 (d, *J* = 7.5 Hz, 2H), 8.46 (d, *J* = 8.2 Hz, 2H).

Mixture of 2-phenyl-4-hydroxy-4-(p-trifluoromethyl-phenyl)-5-(p-methoxyphenyl)-4H-isoimidazole (5h) and 2-phenyl-4-hydroxy-4-(p-methoxyphenyl)-5-(p-trifluoro-methylphenyl)-4H-isoimidazole (5′h). Molar ratio = 10:1, determined by ^{1}H NMR. Pale yellow powder; mp 123–125°C; IR (KBr) 1607 (C=N), 1328 (CF_3), 1263, 1069 (C—O—C) cm^{-1}; UV-vis λ_{max} (CH_2Cl_2) 308 (log ε 4.27), 318 (4.16), 347 (4.12) nm; MS (FAB) *m/z* 427 (M^++1); E.A. Calcd for $C_{23}H_{17}F_3N_2O_2$: C, 67.31; H, 4.18; N, 6.83; Found: C, 67.33; H, 4.15; N, 6.85%. **5h:** ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.91 (s, 3H), 7.02 (d, *J* = 9.0 Hz, 2H), 7.28 (t, *J* = 7.0 Hz, 2H), 7.37 (t, *J* = 7.0 Hz, 1H), 7.58 (d, *J* = 9.2 Hz, 2H), 7.62 (d, *J* = 9.2 Hz, 2H), 8.01 (d, *J* = 7.0 Hz, 2H), 8.28 (d, *J* = 9.0 Hz, 2H).

Preparation of imidazolones.. 0.5 ml of TBAF/THF (1.0 N) was added to a solution of **5** (0.1 mmol) in DMSO, and the mixed solution was stirred for 3 h. Then the reaction mixture was poured into water and the product **4** was precipitated. The crude product was purified by chromatography (silica, hexane:AcOEt = 8:1).

2,5,5-Triphenyl-1H-imidazol-4(5H)-one (4a). mp 222–224°C (lit.[3] 220–222°C); IR (KBr) 1721 (C=O), 1628 (C=N), 698 (Phenyl) cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.28 (t, *J* = 7.0 Hz, 2H), 7.34 (t, *J* = 7.0 Hz, 4H), 7.52 (t, *J* = 7.5 Hz, 2H), 7.58 (t, *J* = 7.5 Hz, 1H), 7.60 (d, *J* = 7.0 Hz, 4H), 7.97 (d, *J* = 7.5 Hz, 2H), 9.11 (br s, 1H); UV-vis λ_{max} (EtOH) 255 (log ε 4.07) nm; MS (FAB) *m/z* 313 (M^++1); E.A. Calcd for $C_{21}H_{16}N_2O$: C, 80.75; H, 5.16; N, 8.97. Found: C, 80.47; H, 5.06; N, 8.94%.

2-(p-Nitrophenyl)-5,5-diphenyl-1H-imidazol-4(5H)-one (4b.) Pale yellow powder; mp 205–206°C; IR (KBr) 1524 (NO_2), 1350 (NO_2) cm^{-1}; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.32 (t, 2H), 7,43 (m, 4H), 7.65 (t, 4H), 8.08 (d, *J* = 9.2 Hz, 2H), 8.18 (d, *J* = 9.2 Hz, 2H), 9.40 (br s, 1H); MS (FAB) *m/z* 358 (M^++1); E.A. Calcd for $C_{21}H_{15}N_3O_3$: C, 66.75; H, 4.13; N, 11.12. Found: C, 66.73; H, 4.00; N, 11.13%.

2-(p-Dimethylaminophenyl)-5,5-diphenyl-1H-imidazol-4(5H)-one (4c). Orange powder, mp 86–88°C; IR (KBr) 1604 (C=N) cm^{-1}; ^{1}H NMR (500 MHz $CDCl_3$) δ 3.04 (s, 6H), 6.45 (d, *J* = 7.5 Hz, 2H), 7.26–7.31 (m, 6H), 7.47–7.51 (m, 4H), 7.93 (d, *J* = 7.5 Hz, 2H), 9.02 (br s, 1H); MS (FAB) *m/z* 356 (M^++1); E.A. Calcd for $C_{23}H_{21}N_3O$: C, 77.72; H, 5.96; N, 11.82. Found: C, 77.70; H, 6.01; N, 11.80.

2-(p-Hydroxyphenyl)-4,5-diphenyl-4H-imidazol-4(5H)-one (4d). Yellow powder; mp 112–114°C (dec.); IR (KBr) 3323 (O—H), 1605 (C=N) cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.05 (d, *J* = 7.6 Hz, 2H), 7.25–7.31 (m, 6H), 7.45–7.50 (m, 4H), 7.98 (d, *J* = 7.6 Hz, 2H), 9.02 (br s, 1H). MS (FAB) *m/z* 329 ($M+H^+$). E.A. Calcd for $C_{21}H_{16}N_2O_2$: C, 76.81; H, 4.91; N, 8.53. Found: C, 76.79; H, 4.92; N, 8.51.

2-(p-Dimethylaminophenyl)-5,5-bis(p-fluorophenyl)-1H-imidazol-4(5H)-one (4e). Orange powder; mp 118–120°C (dec.); IR (KBr) 1605 (C=N) cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.06 (s, 6H), 6.67 (d, *J* = 8.9 Hz, 2H), 6.97–7.15 (t, *J* = 8.8, 4H), 7.57–7.71 (t, *J* = 8.8, 4H), 7.92 (d, *J* = 8.9 Hz, 2H), 9.12 (br s, 1H); MS (FAB) *m/z* 392 (M^++1); E.A. Calcd for $C_{23}H_{19}Cl_2N_3O$: C, 65.10; H, 4.51; N, 9.90. Found: C, 65.12; H, 4.46; N, 9.92.

Table 3

The conditions of HPLC analysis.

	Effluent	Detector wavelength (nm)	Retention time/min I	Retention time/min II
5g	Hexane:2-PrOH 80:20 (V/V)[a]	281	6.1	7.1
5h	Hexane:EtOH 90:10 (V/V)[a]	308	6.3	7.8
4g	EtOH 100%[b]	261	5.4	6.4
4h	EtOH 100%[b]	259	7.0	9.0

[a] Flow rate 1.0 mL/min.
[b] Flow rate 0.7 mL/min.

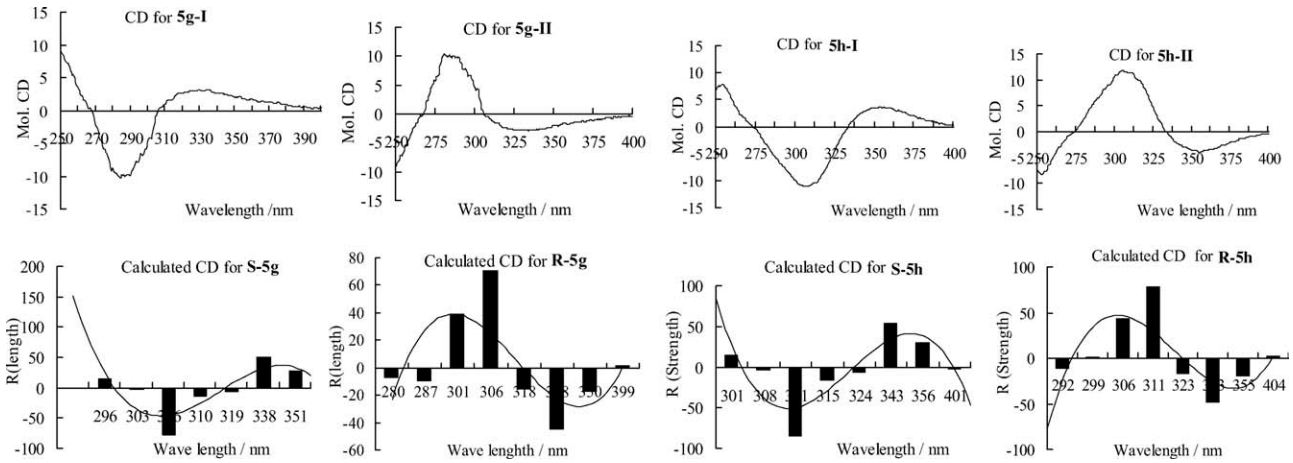


Figure 2. The CD spectra (above) of **5g**, **h** recorded in EtOH and the calculated CD spectra (below) of **5g**, **h** using the TDDFT-B3LYP method. Rotational strengths (*R*) are given in cgs (10^{-40} erg esu cm/Gauss).

2-(p-Dimethylaminophenyl)-5,5-bis(p-chlorophenyl)-1H-imidazol-4(5H)-one (4f). Orange powder; mp 122–124°C (dec.); IR (KBr) 1603 (C=N) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 3.03 (s, 6H), 6.65 (d, J = 8.2 Hz, 2H), 6.90–7.12 (t, J = 8.6 Hz, 4H), 7.61–7.86 (t, J = 8.6, 4H), 7.98 (d, J = 8.2 Hz, 2H), 6.09 (br s, 1H); MS (FAB) *m/z* 425 (M^++1); E.A. Calcd for $C_{23}H_{19}F_2N_3O$: C, 67.81; H, 4.70; N, 10.31. Found: C, 67.35; H, 4.66; N, 10.12.

2-Phenyl-5-(p-fluorophenyl)-5-(p-trifluoromethylphenyl)-1H-imidazol-4(5H)-one (4g). Colorless crystals; mp 82–88°C; IR (KBr) 1734 (C=O), 1618 (C=N), 1328 (CF_3) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.04 (t, J = 8.8 Hz, 2H), 7.55 (t, J = 7.5 Hz, 2H), 7.57–7.64 (m, 5H), 7.75 (d, J = 8.0 Hz, 2H), 7.98 (d, J = 7.5 Hz, 2H), 9.19 (br s, 1H);UV-vis λ_{max} (EtOH) 214 (log ε 4.30), 231 (4.33), 259 (4.02) nm; MS (FAB) *m/z* 399 (M^++1); E.A. Calcd for $C_{22}H_{14}F_4N_2O$: C, 66.33; H, 3.54; N, 7.03. Found: C, 66.40; H, 3.56; N, 6.98%.

2-Phenyl-5-(p-methoxyphenyl)-5-(p-trifluoromethyl-phenyl)-1H-imidazol-4(5H)-one (4h). Colorless crystals; mp 86–90°C; IR (KBr) 1727 (C=O), 1618 (C=N), 1328 (CF_3), 1253, 1071 (C—O—C) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 3.77 (s, 3H), 6.86 (d, J = 9.0 Hz, 2H), 7.48 (d, J = 9.0 Hz, 2H), 7.53 (t, J = 7.0 Hz, 2H), 7.58 (d, J = 8.3 Hz, 2H), 7.60 (t, J = 7.0 Hz, 1H), 7.75 (d, J = 8.3 Hz, 2H), 8.02 (d, J = 7.0 Hz, 2H); UV-vis λ_{max} (EtOH) 214 (log ε 4.33), 232 (4.41) 259 4.08) nm; MS (FAB) *m/z* 411 (M^++1); E.A. Calcd for $C_{23}H_{17}F_3N_2O_2$: C, 67.31; H, 4.18; N, 6.83; Found: C, 67.40; H, 4.16; N, 6.88%

HPLC analysis. The resolution of the racemic imidazolols **5** and the analysis of the EE were carried out using a chiral HPLC column and a HITACHI 561 recorder, as shown in Figure 1. The conditions are summarized in Table 3.

Assignment of absolute configuration by comparison of experimental and calculated CD spectra. To determine the absolute configuration, the CD spectra were recorded and calculated using the Gaussian 03w software package, [9] as shown in Figures 2 and 3. A geometry optimization was performed using the B3LYP functional with 6-31G* basis sets. The absolute configurations of **5-I** and **5-II** in the HPLC spectra were assigned as **S-5** and **R-5**, respectively, as shown in

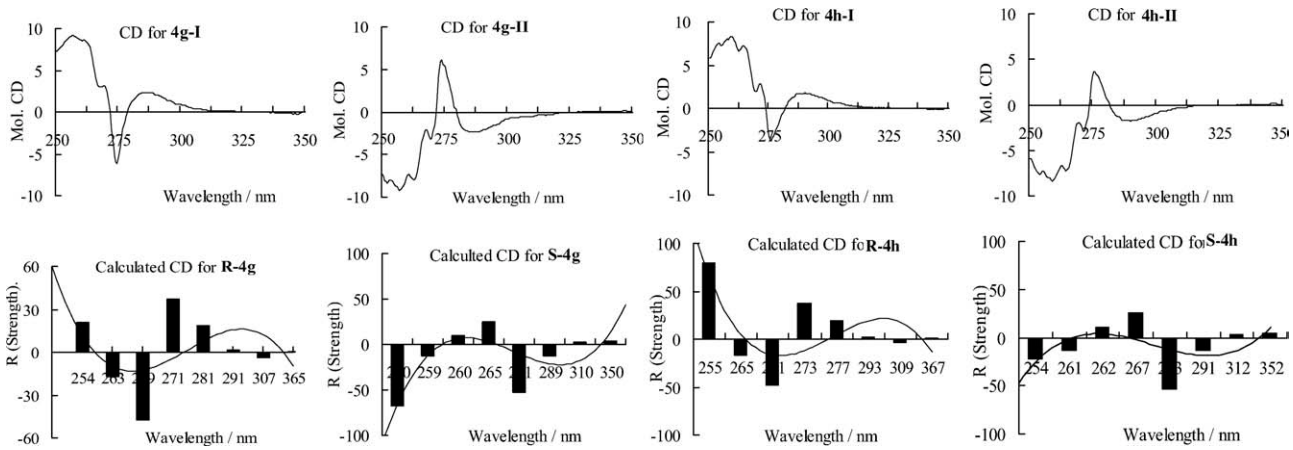


Figure 3. The CD spectra (above) of **4g**, **h** recorded in EtOH and the calculated CD spectra (below) of **4g**, **h** using the TDDFT-B3LYP method. Rotational strengths (*R*) are given in cgs (10^{-40} erg esu cm/Gauss).

Figure 2. In the same manner, the absolute configurations of products **4-I** (HPLC: first fraction) and **4-II** (HPLC: second fraction) were also assigned to **R-4** and **S-4**, respectively, as shown in Figure 3.

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