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Note

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Nickel-Catalyzed Transformation of Alkene-Tethered Oxime Ethers to Nitriles by a Traceless Directing Group Strategy

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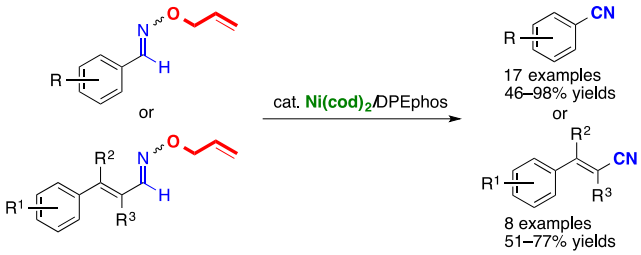
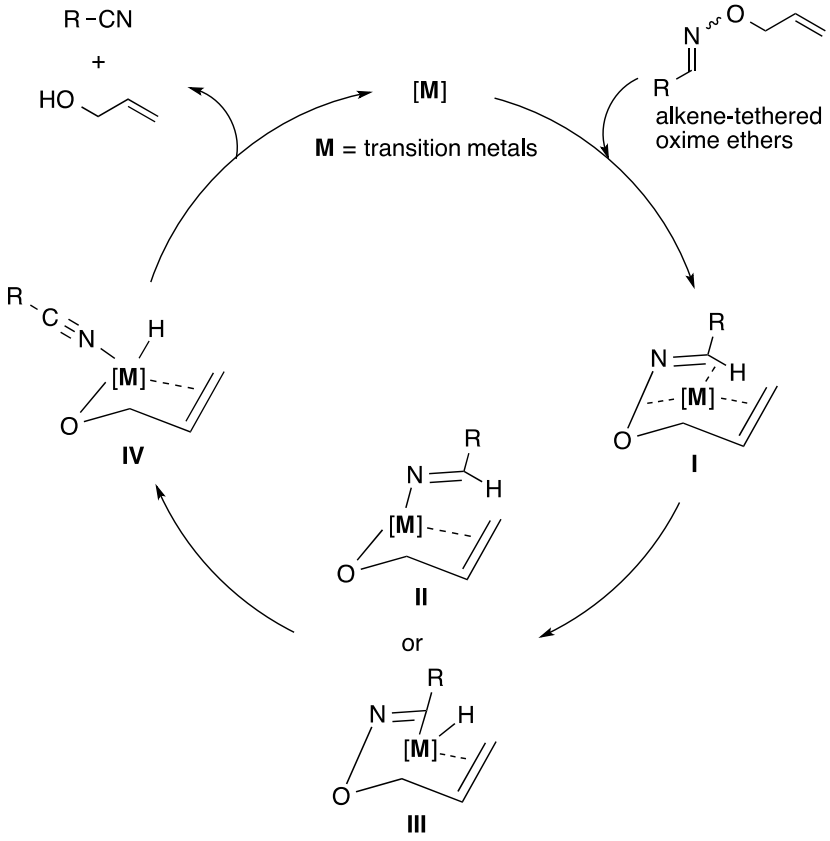


Abstract: Nickel-catalyzed transformation of alkene-tethered oxime ethers to nitriles using a traceless directing group strategy has been developed. A series of alkene-tethered oxime ethers derived from benzaldehyde and cinnamyl aldehyde derivatives were converted into the corresponding benzonitriles and cinnamonitriles in 46–98% yields using the nickel catalyst system. Control experiments showed that the alkene group tethered to an oxygen atom on the oximes via one methylene unit plays a key role as a traceless directing group during the catalysis.

The transition-metal-catalyzed substrate-directed reaction provides an efficient tool accessing to complex organic molecules in chemo-, regio-, and enantioselective fashions.[1] Although the method has made a great contribution to the progress of organic synthesis, the use of existing functional groups on the substrates is necessary for achieving the directed reaction, and the installation of the directing group and its removal are required via additional chemical steps. As one of the strategies that overcomes these drawbacks, the traceless directing group strategy has recently received much attention, because the directing group is tracelessly cleavable during the catalysis.[2] While this strategy has been utilized for the development of the transition-metal-catalyzed C-H and B-H functionalization reactions,[3,4] only scattered attention has been paid for its application to the other organic transformations.[5] Herein, we report the nickel-catalyzed transformation of alkene-tethered oxime ethers to nitriles using a traceless directing group strategy.

Nitrile is one of the most important and fundamental constituents in biologically active compounds,[6] natural products,[7] functional materials[8] as well as synthetic intermediates.[9] Due to the prominent importance of the nitrile in organic synthesis, various synthetic methods have already been developed.[10] The catalytic transformation of oxime derivatives into nitriles is one of the useful approaches for the synthesis of nitriles.[11,12] Although various catalyst systems have been established, developing a novel method that utilizes oximes as an accessible starting material continues to be an active area of research in the synthetic organic chemistry. In this context, we envisioned that alkene-tethered oxime ethers would be converted into nitriles in the presence of a transition metal catalyst, proving a novel method for the catalytic synthesis of nitriles from oxime derivatives as shown in Scheme 1. Initially, the oxidative addition of a N-O bond[13] or an oxime C-H bond[14] of the alkene-tethered oxime ethers to a low valent metal center would occur via intermediate **I** to generate intermediate **II** or **III**. As shown in intermediate **I**, we speculate that the oxidative addition step might be accelerated by the directing effect of the alkene group to the metal center.[15] Subsequent β-hydride elimination from intermediate **II** or β-oxygen elimination from intermediate **III**[16] would produce intermediate **IV** that undergoes reductive elimination to give the desired nitriles along with the formation of allyl alcohol and regeneration of the low valent metal catalyst.

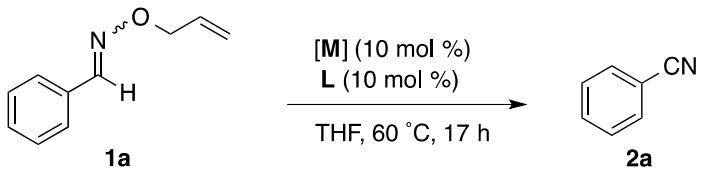
Scheme 1. Our Working Hypothesis



Based on this hypothesis, we initially examined the trans-formation of alkene-tethered oxime ether **1a** into benzonitrile (**2a**) in the presence of several transition metals as the catalyst in THF at 60 ˚C for 17 h (Table 1). The alkene-tethered oxime ether **1a** can be easily prepared by the reaction of benzaldehyde with *O*-allylhydroxylamine hydrochloride (Details for the preparation of alkene-tethered oxime ethers, see experimental section). $[Cp^*Ru(CH_3CN)_3]PF_6$ showed the catalytic activity in the transformation, producing benzonitrile (**2a**) in 79% GC yield (entry 1). The use of $[RhCl(cod)]_2$ and $[IrCl(cod)]_2$ as the metal catalysts led to unsatisfactory yields (Entries 2 and 3). We were pleased to find that $Ni(cod)_2$ exhibited the high catalytic activity, providing **2a** in 95% GC yield (Entry 4). In contrast, the reaction did not take place in the presence of $Pd_2(dba)_3•CHCl_3$, $Pd(PPh_3)_4$, $Pt(C_2H_4)(PPh_3)_2$, and CuCl as the catalysts (Entries 5–8). We next tested the other phosphine ligands using $Ni(cod)_2$ as the metal catalyst. The nickel catalyst systems consisting of DPPE and DPPP as the bidentate ligands showed the poor catalytic activity (Entries 9 and 10). The transformation of **1a** in the presence of the $Ni(cod)_2$/DPPB catalyst system afforded

2a in 70% yield (Entry 11). When DPPPent, DPEphos, and Xantphos were used as the ligands, the desired product **2a** was formed in high yields (Entries 12–14).

Table 1. Screening of Transition-metal Catalysts and Ligands[a]



1a 2a

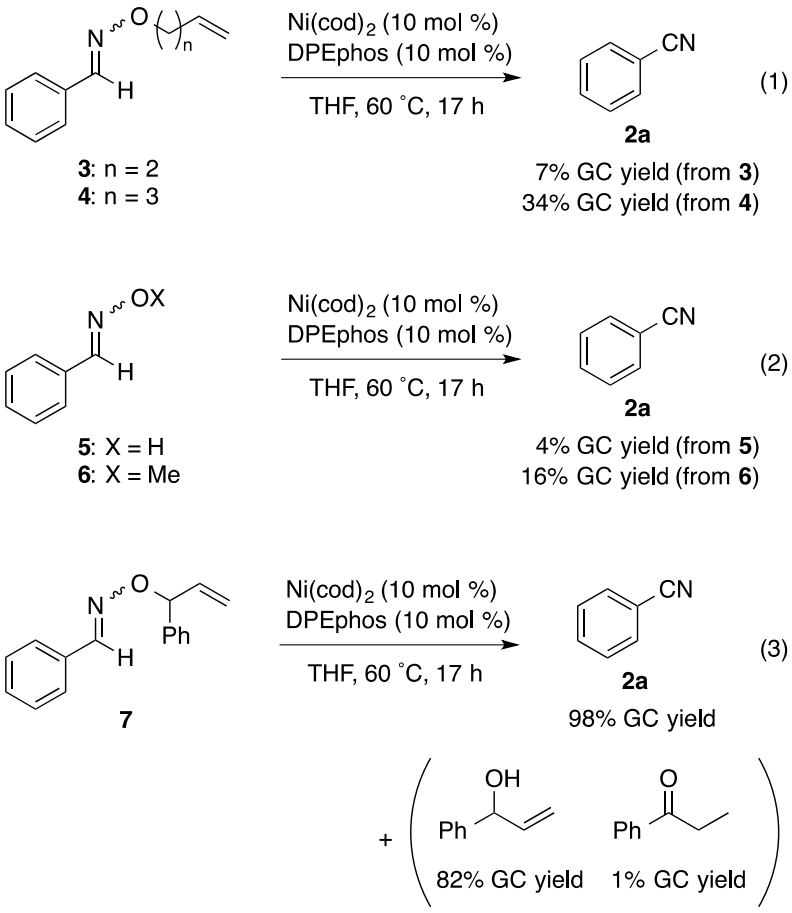
entry	**M**	**L**	conv.[b] (%)	yield[b] (%)
1	$[Cp^*Ru(CH_3CN)_3]PF_6$	DPPF	88	79
2[c]	$[RhCl(cod)]_2$	DPPF	28	24
3[c]	$[IrCl(cod)]_2$	DPPF	36	29
4	$Ni(cod)_2$	DPPF	>99	95
5[c]	$Pd_2(dba)_3•CHCl_3$	DPPF	7	<1
6	$Pd(PPh_3)_4$	–	<1	<1
7	$Pt(C_2H_4)(PPh_3)_2$	–	10	<1
8	CuCl	DPPF	2	<1
9	$Ni(cod)_2$	DPPE	36	25
10	$Ni(cod)_2$	DPPP	17	15
11	$Ni(cod)_2$	DPPB	80	70
12	$Ni(cod)_2$	DPPPent	>99	91
13	$Ni(cod)_2$	DPEphos	>99	98
14	$Ni(cod)_2$	Xantphos	>99	97
15[d]	$Ni(cod)_2$	PPh_3	>99	87
16	$Ni(cod)_2$	–	47	47

[a]Reaction conditions: **1a** (0.3 mmol, as a 94:6 mixture of stereoisomers), **M** (0.03 mmol), **L** (0.03 mmol) in THF (1.2 mL) at 60 °C for 17 h. [b]Determined by GC analysis using *n*-octane as an internal standard. [c]With 5 mol% metal catalysts. [d]With 20 mol% of PPh_3.

In particular, a combination of $Ni(cod)_2$ and DPEphos was the most effective for this transformation, and the catalyst system furnished **2a** in 98% GC yield (Entry 13). Replacing the bidentate phosphine ligand to monodenate one led to a slight decrease of the catalytic performance (Entry 15). The reaction also took place in the absence of phosphine ligands to give **2a** albeit with moderate yield (Entry 16).

With a suitable metal catalyst in hand, we next investigated several control experiments to elucidate the effect of the traceless directing group in this transformation (Scheme 2). Initially, we evaluated the effect of the tether length between the terminal alkene and oxygen atom on the oxime (Scheme 2, eq 1). When oxime ether **3** including two methylene units was subjected to the optimized reaction conditions, the desired benzonitrile **2a** was formed in only 7% GC yield. The use of oxime ether **4** bearing three methylene units also led to the diminished yield of **2a**.

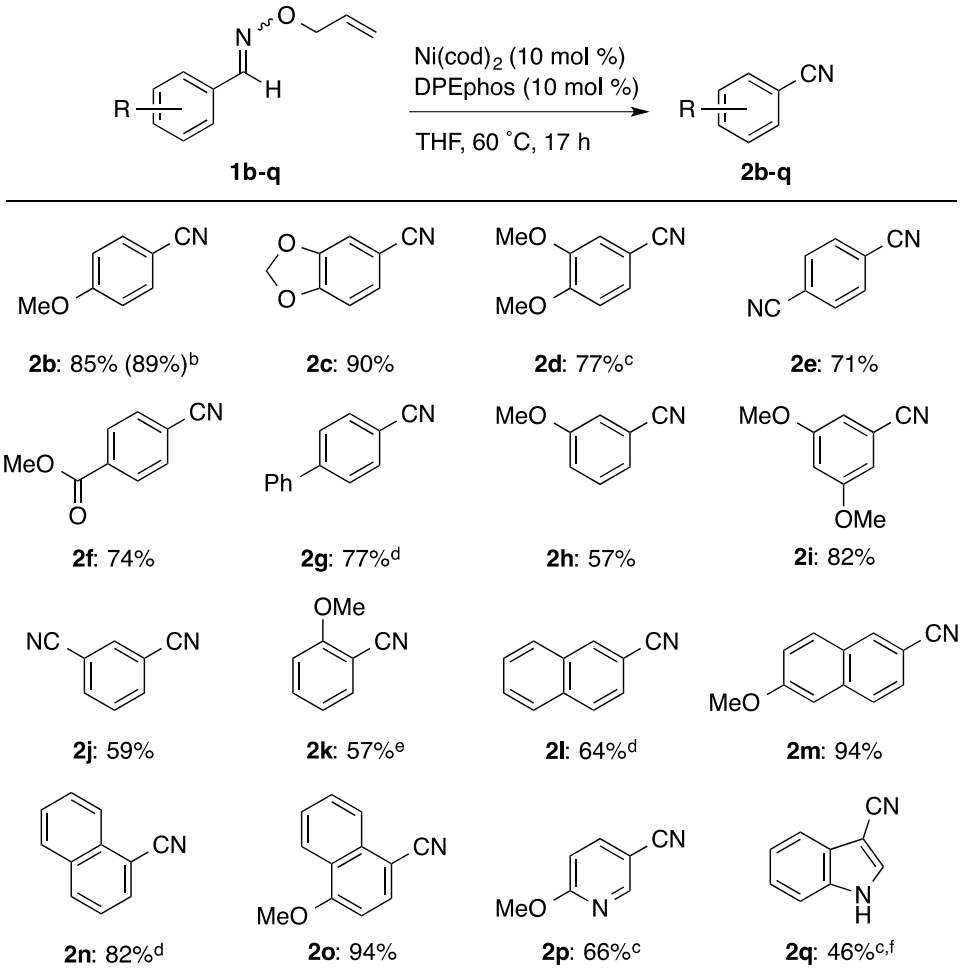
Scheme 2. Control Experiments



We next examined the reaction of oxime **5** and oxime methyl ether **6** containing no alkene groups. As a result, the reaction of these substrates yielded **2a** in low yield (Scheme 2, eq 2). These results indicated that the alkene group tethered to an oxygen atom on the oxime via the one methylene unit is essential to proceed the directed transformation.[17,18] Additionally, we also carried out the transformation of secondary oxime ether **7** under the same reaction conditions (Scheme 2, eq. 3). GC analysis of the reaction mixture showed that **2a**, 1-phenyl-2-propen-1-ol, and propiophenone[19] were formed in 98%, 82%, and 1% GC yield, respectively. This result indicated that the present catalysis would be involved in the oxidative addition of a N-O bond or an oxime C-H bond to Ni(0) and subsequent β-hydride elimination or β-oxygen elimination/reductive elimination sequence as shown in Scheme 1.

We next examined the transformation of alkene-tethered oxime ethers **1** bearing various substituents to nitriles under the optimized reaction conditions (Scheme 3). The reaction of oxime ether **1b** bearing a 4-methoxyphenyl group proceeded smoothly to give the desired benzonitrile derivative **2b** in 85% yield. In addition, the reaction could be carried out on a 3 mmol scale without any loss of the catalytic performance, giving **2b** in 89% yield. Electron-rich (**1c**, **1d**) and -poor (**1e**, **1f**) substrates were well tolerated to give nitriles **2c**–**f** in 71–90% yields. 4-Biphenylcarbonitrile (**2g**) was obtained in 77% yield by the reaction of oxime ether **1g** using triphenylphosphine as the ligand because nitrile **2g** and DPEphos were inseparable by silica-gel column chromatography. Oxime ethers **1h**–**j** having methoxy and cyano substituents at the meta-position on their phenyl ring also underwent the reaction to afford the corresponding nitriles **2h**–**j** in 57–82% yields. The reaction of oxime ether **1k** took place at 100 ˚C in 1,4-dioxane probably due to the steric effect of the *ortho* methoxy group on the phenyl ring to give nitrile **2k** in 57% yield. Naphthonitriles (**2l**, **2n**) and their derivatives (**2m**, **2o**) were obtained in 64–94% yields from the corresponding alkene-tethered oxime ethers **1l**–**o** using the nickel catalyst system. Although slightly harsh conditions were required, the present nickel catalysis was also applicable to the transformation of oxime ethers derived from pyridine (**1p**) and indole (**1q**), providing nitriles **2p** and **2q** in satisfactory yields. We also examined the reaction of alkene-tethered oxime ethers bearing chlorine, bromine, amide, and nitro groups on the phenyl rings. However, the reaction of these substrates did not work well under the nickel catalysis. In addition, we also carried out the reaction of

Scheme 3. Scope of Alkene-Tethered Oxime Ethers 1[a]



[a]Reaction conditions: **1** (0.6 mmol, as a mixture of stereoisomers), $Ni(cod)_2$ (0.06 mmol), DPEphos (0.06 mmol) in THF (2.4 mL) at 60 ˚C for 17 h. Isolated yields were shown. [b]3 mmol scale. [c]The reaction was performed in 1,4-dioxane at 80 ˚C. [d]PPh_3 (20 mol%) was used instead of DPEPhos. [e]The reaction was performed in 1,4-dioxane at 100 ˚C. [f]The reaction was carried out for 48 h.

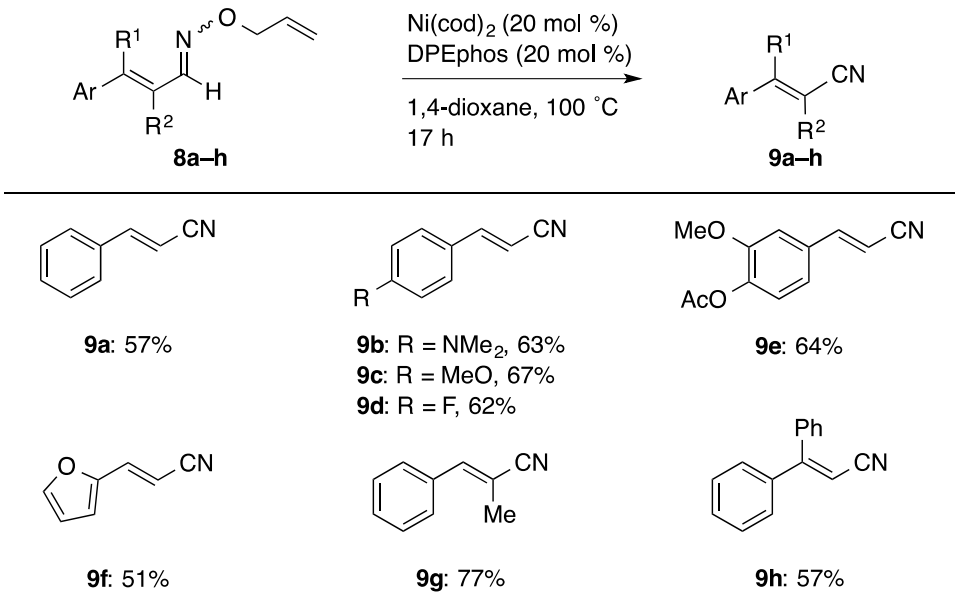
the aliphatic oxime ether having a phenethyl group, but the desired aliphatic nitrile was not obtained.

We next turned our attention to the transformation of alkene-tethered oxime ethers derived from cinnamyl aldehyde derivatives into alkenylnitriles using the traceless directing group strategy (Scheme 4). The reaction of alkene-tethered oxime ether **8a** proceeded in the presence of 20 mol% of $Ni(cod)_2$ and DPEphos at 100 ˚C to give the desired cinnamonitrile (**9a**) in 57% yield. We assumed that the requirement of

the slightly higher loading amount of the catalyst and elevated reaction temperature would be attributed to the coordination of the alkene group of the substrate and the product to the nickel center. *p*-Dimethylamino (**8b**), *p*-methoxy (**8c**), and *p*-fluoro (**8d**) substituents on the phenyl rings did not affect the reaction efficiency, providing the desired nitriles **9b**–**d** in 62–67% yields. 4-Acetoxy-3-methoxyphenyl (**8e**) and furanyl (**8f**) rings were compatible with the reaction conditions to give the desired nitriles **9e** and **9f** in 64% and 51% yield, respectively. Oxime ether **8g** bearing a methyl substituent at the α position also be applicable to the nickel catalysis, affording α-methyl cinnamonitrile **9g** in 77% yield. In addition, the reaction of **8h** having a phenyl group at the β position took place to give nitrile **9h** in 57% yield.

In conclusion, we have developed the nickel-catalyzed transformation of alkene-tethered oxime ethers to nitriles in which the alkene group tethered to an oxygen atom on the oxime via one methylene unit plays a critical role as a traceless directing group. A wide variety of functionalized benzonitrile and cinnamyl nitrile derivatives

Scheme 4. Transformation of Alkene-Tethered Oxime Ethers 8 into Alkenylnitriles 9



[a]Reaction conditions: **8** (0.6 mmol, as a mixture of stereoisomers), $Ni(cod)_2$ (0.12 mmol), DPEphos (0.12 mmol) in 1,4-dioxane (2.4 mL) at 100 ˚C for 17 h. Isolated yields were shown.

could be prepared in good yields by the nickel-catalyzed traceless directing group strategy. The development of other organic transformations using the novel traceless directing group is currently underway in our laboratory.

Experimental Section

General Information

Commercially available chemicals were purchased from Aldrich, TCI, Kanto, and Wako and used without further purification unless otherwise noted. But-3-en-1-yl 4-methylbenzenesulfonate and pent-4-en-1-yl 4-methylbenzenesulfonate were prepared by the reaction of the corresponding alcohols with TsCl. NMR spectra were recorded at 25 ˚C on a JEOL EX-270 spectrometer (270 MHz for ^{1}H, 67.8 MHz for ^{13}C{^{1}H}) or a JEOL JNM ECP-500 spectrometer (126 MHz for ^{13}C{^{1}H}, 471 MHz for ^{19}F). Chemical shifts are reported in δ□ppm referenced to an internal tetramethylsilane (0 ppm) for ^{1}H NMR. Chemical shifts of ^{13}C NMR are given relative to the solvent peak as an internal standard. ^{19}F NMR data are reported relative to external α,α,α-trifluorotoluene (–63.7 ppm). Multiplicities are indicated as br (broad), s (singlet), d (doublet), t (triplet), q (quartet), or m (multiplet). Coupling constants (J) are reported in Hertz (Hz). Melting points were measured on a Yanako MP-500P. Infrared (IR) spectra were recorded on JASCO FT/IR-460. GC analyses were carried out using a SHIMADZU GC-2014AFsc. HRMS analyses were carried out using a JEOL AccuTOF LCplus for ESI-MS and APCI-MS and JEOL GCmate for EI-MS. Column chromatography and preparative thin-layer chromatography were conducted with silica gel 60N (KANTO CHEMICAL, spherical, neutral, 40-50 or 63-210 μm) and Wakogel® B-5F (45 μm), respectively. For thin-layer chromatography (TLC) analyses throughout this work, Merck precoated TLC plates (silica gel 60 F254 0.25 mm) were used. Visualization was accomplished by UV light (254 nm), phosphomolybdic acid. Oil bath was used as the heat source for the reactions that require heating.

General procedure for the preparation of starting materials

Preparation of benzaldehyde *O*-allyl oxime (1a)[20]

Sodium acetate (615 mg, 7.5 mmol, 1.5 equiv) and *O*-allylhydroxylamine hydrochloride (657 mg, 6.0 mmol 1.2 equiv) were charged into a round flask. After the addition of MeOH (14 mL) and H_2O (1.3 mL) into the flask, benzaldehyde (0.51 mL, 5.0 mmol)

was added dropwise to the mixture at room temperature. The reaction mixture was stirred at room temperature overnight. The resulting mixture was concentrated by evaporation and then H_2O was added. The resulting aqueous phase was extracted with EtOAc (20 mL×3). The combined organic phase was washed with water (30 mL×3), brine, dried over MgSO4. After removal of the solvent, the resulting crude mixture was purified by silica gel column chromatography (Hexane/EtOAc = 99/1) to give benzaldehyde *O*-allyl oxime (1a) as a yellow oil (541 mg, 3.35 mmol, 67% yield as a 94:6 mixture of stereoisomers). ^{1}H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 4.68 (ddd, *J* = 5.9 1.4, 1.4 Hz, 2H), 5.25 (ddt, *J* = 10.4, 1.6, 1.4 Hz, 1H), 5.36 (ddt, *J* = 17.3, 1.6, 1.4 Hz, 1H), 6.06 (ddt, *J* = 17.3, 10.4, 5.9 Hz, 1H), 7.33–7.42 (m, 3H), 7.55–7.64 (m, 2H), 8.12 (s, 1H); (*minor* isomer) δ 4.73 (ddd, *J* = 5.7, 1.4, 1.4 Hz, 2H), 7.87–7.92 (m, 2H), the other peaks were not found probably due to overlapping.; ^{13}C{^{1}H} NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 75.0, 117.7, 126.9, 128.5, 129.6, 132.1, 134.0, 148.6; (*minor* isomer) δ 75.6, 117.4, 128.3, 129.8, 130.8, 134.1, 145.9, one peak was not found probably due to overlapping.; GC-MS (EI): *m*/*z* 160 $[M-H]^+$.

4-Methoxybenzaldehyde *O*-allyl oxime (**1b**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 99/1). Pale yellow oil (155 mg, 0.812 mmol, 81% yield as a 93:7 mixture of stereoisomers); IR (neat) 3079, 2933, 2838, 1607, 1513, 1252, 1109, 1031, 831 cm^{-1}; ^{1}H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 3.82 (s, 3H), 4.65 (ddd, *J* = 5.9, 1.4, 1.4 Hz, 2H), 5.24 (ddt, *J* = 10.4, 1.8, 1.4 Hz, 1H), 5.35 (ddt, *J* = 17.5, 1.8, 1.4 Hz, 1H), 6.05 (ddt, *J* = 17.5, 10.4, 5.9 Hz, 1H), 6.86–6.91 (m, 2H), 7.49–7.54 (m, 2H), 8.07 (s, 1H); (*minor* isomer) δ 3.83 (s, 3H), 4.71 (ddd, *J* = 5.7, 1.5, 1.5 Hz, 2H), 7.87–7.90 (m, 2H), the other peaks were not found probably due to overlapping.; ^{13}C{^{1}H} NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 55.3, 75.0, 114.1, 117.8, 128.5, 134.1, 148.5, 160.9, one peak for aromatic carbon was not found probably due to overlapping.; (*minor* isomer) δ 75.6, 113.7, 124.8, 132.9, 145.7, the other peaks were not found probably due to overlapping.; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{11}H_{14}NO_2$ 192.1025; Found 192.1022.

Benzo[*d*][1,3]dioxole-5-carbaldehyde *O*-allyl oxime (**1c**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 99/1). Yellow oil (563 mg, 2.74 mmol, 91% yield as a 99:1 mixture of stereoisomers); IR (neat) 3081, 2989, 2904, 2782, 1595, 1504, 1449, 1250, 1038, 931, 809 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 4.64 (ddd, *J* = 5.7, 1.4, 1.4 Hz, 2H), 5.24 (ddt, *J* = 10.1, 1.5, 1.4 Hz, 1H), 5.34 (ddt, *J* = 17.2, 1.5, 1.4 Hz, 1H), 5.97–6.12 (m, 3H), 6.79 (d, *J* = 8.1 Hz, 1H), 6.94 (dd, *J* = 8.1, 1.6 Hz, 1H), 7.20 (d, *J* = 1.6 Hz, 1H), 8.02 (s, 1H); (*minor* isomer) δ 4.70 (ddd, *J* = 5.9, 1.5, 1.5 Hz, 2H), the other peaks were not found probably due to overlapping.; $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 75.0, 101.3, 105.6, 108.2, 117.8, 122.8, 126.5, 134.0, 148.1, 148.4, 149.1; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{11}H_{12}NO_3$ 206.0817; Found 206.0807.

3,4-Dimethoxybenzaldehyde *O*-allyl oxime (**1d**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 95/5, 9/1, 4/1, 7/3). Yellow oil (662 mg, 2.99 mmol, >99% yield as a 93:7 mixture of stereoisomers); IR (neat) 3081, 2935, 2837, 1602, 1514, 1264, 1027, 809 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 3.90 (s, 3H), 3.92 (s, 3H), 4.67 (ddd, *J* = 5.9, 1.5, 1.5 Hz, 2H), 5.22–5.28 (m, 1H), 5.35 (ddt, *J* = 17.2, 1.8, 1.5 Hz, 1H), 6.06 (ddt, *J* = 17.2, 10.5, 5.9 Hz, 1H), 6.84 (d, *J* = 8.3 Hz, 1H), 7.01 (dd, *J* = 8.3, 1.8 Hz, 1H), 7.24 (d, *J* = 1.8 Hz 1H), 8.05 (s, 1H); (*minor* isomer) δ 4.72 (ddd, J = 5.4, 1.3, 1.3 Hz 2H), 6.89 (d, J = 8.3 Hz 1H), 7.42 (dd, *J* = 8.3, 2.0 Hz, 1H), 7.64 (d, *J* = 2.0 Hz, 1H), the other peaks were not found probably due to overlapping.; $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 55.7, 74.8, 107.8, 110.5, 117.7, 121.5, 124.9, 134.0, 148.5, 149.1, 150.5, one peak for methoxy carbon was not found probably due to overlapping.; (*minor* isomer) δ 75.5, 110.3, 113.6, 117.3, 124.8, 145.7, the other peaks were not found probably due to overlapping.; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{12}H_{16}NO_3$ 222.1130; Found 222.1133.

4-(((Allyloxy)imino)methyl)benzonitrile (**1e**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography

(Hexane/EtOAc = 9/1, 4/1). White solid (529 mg, 2.84 mmol, 94% yield as a 84:16 mixture of stereoisomers); M.p. 48.5-50.4 ˚C; IR (KBr) 3087, 2921, 2866, 2227, 1604, 1109, 929, 835, cm^{-1}; ^{1}H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 4.70 (ddd, *J* = 5.9, 1.4, 1.4 Hz, 2H), 5.26 (ddt, *J* = 10.5, 1.4, 1.4 Hz, 1H), 5.36 (ddt, *J* = 17.1, 1.4, 1.4 Hz, 1H), 6.04 (ddt, *J* = 17.1, 10.5, 5.9 Hz, 1H), 7.62–7.70 (m, 4H), 8.10 (s, 1H); (*minor* isomer) δ 4.75 (ddd, *J* = 5.7, 1.4, 1.4 Hz, 2H), 7.37 (s, 1H), 7.97–8.00 (m, 2H), the other peaks were not found probably due to overlapping.; $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 75.9, 113.2, 118.6, 118.7, 127.6, 132.7, 133.9, 136.8, 147.2; (*minor* isomer) δ 76.5, 113.4, 118.5, 131.3, 132.4, 134.3, 144.4, the other peaks were not found probably due to overlapping.; HRMS (EI) *m*/*z*: $[M]^+$ Calcd for $C_{11}H_{10}N_2O$ 186.0793; Found 186.0797.

Methyl 4-(((allyloxy)imino)methyl)benzoate (**1f**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 95/5, 92/8, 9/1). White solid (632 mg, 2.88 mmol, 95% yield as a 92:8 mixture of stereoisomers); M.p. 36.1–38.3 ˚C; IR (KBr) 3086, 2958, 2873, 1719, 1609, 1285, 1038, 818 cm^{-1}; ^{1}H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ□3.92 (s, 3H), 4.71 (ddd, *J* = 5.9, 1.5, 1.5 Hz, 2H), 5.27 (ddt, *J* = 10.5, 1.6, 1.5 Hz, 1H), 5.36 (ddt, *J* = 17.2, 1.6, 1.5 Hz, 1H), 6.05 (ddt, *J* = 17.2, 10.5, 5.9 Hz, 1H), 7.63–7.67 (m, 2H), 8.01–8.06 (m, 2H), 8.14 (s, 1H); (*minor* isomer)□δ□3.93 (s, 3H),□4.75 (ddd, *J* = 5.7, 1.4, 1.4 Hz, 2H), 7.39 (s, 1H), 7.94–7.97 (m, 2H), 8.09 (m, 1H), the other peaks were not found probably due to overlapping.; $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ□52.1, 75.4, 118.1, 126.8, 129.8, 130.9, 133.7, 136.4, 147.7, 166.4; (*minor* isomer) δ 52.2, 76.0, 117.8, 129.5, 130.6, 133.8, 145.0, the other peaks were not found probably due to overlapping; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{12}H_{14}NO_3$ 220.0974; Found 220.0976.

[1,1'-Biphenyl]-4-carbaldehyde *O*-allyl oxime (**1g**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 99/1). Pale yellow solid (677 mg, 2.85 mmol, 94% yield as a 97:3 mixture of stereoisomers); M.p. 42.0–44.1 ˚C; IR (KBr) 3085, 2925, 2871, 1607, 1035,

832, 763 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 4.69 (ddd, *J* = 5.9, 1.5, 1.5 Hz, 2H), 5.25 (ddt, *J* = 10.3, 1.6, 1.5 Hz, 1H), 5.34 (ddt, *J* = 17.4, 1.6, 1.5 Hz, 1H), 6.06 (ddt, *J* = 17.4, 10.3, 5.9 Hz, 1H), 7.31–7.37 (m, 1H), 7.39–7.46 (m, 2H), 7.56–7.66 (m, 6H), 8.14 (s, 1H); (*minor* isomer) δ 4.74 (ddd, *J* = 5.4, 1.5, 1.5 Hz, 2H), 7.95–7.98 (m, 4H), the other peaks were not found probably due to overlapping.; $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 75.2, 118.0, 127.0, 127.3, 127.5, 127.7, 128.8, 131.1, 134.0, 140.3, 142.5, 148.5; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{16}H_{16}NO$ 238.1232; Found 238.1223.

3-Methoxybenzaldehyde *O*-allyl oxime (**1h**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 99/1). Yellow oil (495 mg, 2.59 mmol, 86% yield as a 96:4 mixture of stereoisomers); IR (neat) 3078, 2920, 2836, 1599, 1577, 1264, 1041, 783 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 3.83 (s, 3H), 4.68 (ddd, *J* = 5.8, 1.5, 1.5 Hz, 2H), 5.22–5.28 (m, 1H), 5.35 (ddt, *J* = 17.1, 1.8, 1.5 Hz, 1H), 6.05 (ddt, *J* = 17.1, 10.3, 5.8 Hz, 1H), 6.92 (ddd, *J* = 8.1, 2.7, 0.95 Hz, 1H), 7.11–7.17 (m, 2H), 7.28 (dd, *J* = 8.1, 8.1 Hz, 1H), 8.08 (s, 1H); (*minor* isomer) δ 4.72 (ddd, *J* = 5.7, 1.5, 1.5 Hz, 2H), the other peaks were not found probably due to overlapping.; $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 55.3, 75.2, 111.1, 116.1, 118.0, 120.1, 129.6, 133.5, 133.9, 148.7, 159.7; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{11}H_{14}NO_2$ 192.1025; Found 192.1023.

3,5-Dimethoxybenzaldehyde *O*-allyl oxime (**1i**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 85/15, 4/1). Pale yellow oil (631 mg, 2.85 mmol, 94% yield as a 98:2 mixture of stereoisomers); IR (neat) 3082, 2938, 2840, 1615, 1586, 1206, 1156, 1037, 837 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 3.80 (s, 6H), 4.68 (ddd, *J* = 5.9, 1.4, 1.4 Hz, 2H), 5.25 (ddt, *J* = 10.4, 1.6, 1.4 Hz, 1H), 5.35 (ddt, *J* = 17.0, 1.6, 1.4 Hz, 1H), 6.05 (ddt, *J* = 17.0, 10.4, 5.9 Hz, 1H), 6.47 (t, *J* = 2.3 Hz, 1H), 6.73 (d, *J* = 2.4 Hz, 2H), 8.03 (s, 1H); (*minor* isomer) δ 4.72 (ddd, *J* = 5.7, 1.5, 1.5 Hz, 2H), 6.52 (t, *J* = 2.3 Hz, 1H), 7.07 (d, *J* = 2.2 Hz, 2H), the other peaks were not found probably due to

overlapping.; $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 55.3, 75.1, 102.3, 104.8, 117.9, 133.9, 134.0, 148.7, 160.8; (*minor* isomer) δ 75.7, 102.4, 108.8, 117.5, 145.9, 160.4, the other peaks were not found probably due to overlapping.; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{12}H_{16}NO_3$ 222.1130; Found 222.1134.

3-(((Allyloxy)imino)methyl)benzonitrile (**1j**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 95/5, 9/1). Yellow oil (483 mg, 2.59 mmol, 85% yield as a 9:1 mixture of stereoisomers); IR (neat) 3081, 2925, 2871, 2232, 1612, 1156, 1033, 927 cm^{-1}; ^{1}H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 4.70 (ddd, *J* = 5.8, 1.5, 1.5 Hz, 2H), 5.25–5.30 (m, 1H), 5.36 (ddt, *J* = 17.2, 1.6, 1.5 Hz, 1H), 6.04 (ddt, *J* = 17.2, 10.4, 5.8 Hz, 1H), 7.49 (dd, *J* = 7.8, 7.8 Hz, 1H), 7.64 (ddd, *J* = 7.8, 1.6, 1.6 Hz, 1H), 7.79 (ddd, *J* = 7.8, 1.6, 1.6 Hz, 1H), 7.89 (dd, *J* = 1.6, 1.6 Hz, 1H), 8.10 (s, 1H); (*minor* isomer) δ 4.76 (ddd, *J* = 5.4, 1.3, 1.3 Hz, 2H), 7.34 (s, 1H), 7.54–7.57 (m, 1H), 8.01 (ddd, *J* = 7.8, 1.5, 1.5 Hz, 1H), 8.32 (dd, *J* = 1.5, 1.5 Hz 1H), the other peaks were not found probably due to overlapping.; $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 75.9, 113.3, 118.5, 118.6, 129.8, 130.5, 131.3, 133.1, 133.9, 134.0, 146.8; (*minor* isomer) δ 76.5, 113.1, 129.7, 131.7, 133.3, 134.5, 135.0, 143.9, the other peaks were not found probably due to overlapping.; HRMS (EI) *m*/*z*: $[M]^+$ Calcd for $C_{11}H_{10}N_2O$ 186.0793; Found 186.0794.

2-Methoxybenzaldehyde *O*-allyl oxime (**1k**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 99/1). Pale yellow oil (522 mg, 2.73 mmol, 91% yield as a 96:4 mixture of stereoisomers); IR (neat) 3078, 2936, 2839, 1607, 1253, 1028, 754 cm^{-1}; ^{1}H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 3.83 (s, 3H), 4.67 (ddd, *J* = 5.4, 1.4, 1.4 Hz, 2H), 5.24 (ddt, *J* = 10.7, 1.6, 1.4 Hz, 1H), 5.35 (ddt, *J* = 17.3, 1.6, 1.4 Hz, 1H), 5.98–6.13 (m, 1H), 6.87–6.97 (m, 2H), 7.30–7.36 (m, 1H), 7.78 (dd, *J* = 7.7, 1.8 Hz, 1H), 8.51 (s, 1H); (*minor* isomer) δ 3.85 (s, 3H), 4.70–4.71 (m, 2H), the other peaks were not found probably due to overlapping.; $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 55.5, 75.0, 111.0, 117.7, 120.7, 120.8, 126.4, 131.0, 134.2, 145.0, 157.5; (*minor*

isomer) δ 75.5, 110.6, 117.3, 120.1, 132.0, 141.2, the other peaks were not found probably due to overlapping.; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{11}H_{14}NO_2$ 192.1025; Found 192.1022.

2-Naphthaldehyde *O*-allyl oxime (**1l**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 95/5). White semi-solid (610 mg, 2.89 mmol, 96% yield as a 94:6 mixture of stereoisomers); IR (neat) 3059, 2919, 2866, 1609, 1125, 1037, 933, 820, 746 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 4.73 (ddd, *J* = 5.6, 1.3, 1.3 Hz, 2H), 5.28 (ddt, *J* = 10.2, 1.7, 1.3 Hz, 1H), 5.39 (ddt, *J* = 17.4, 1.7, 1.3 Hz, 1H), 6.09 (ddt, *J* = 17.4, 10.2, 5.6 Hz, 1H), 7.46–7.56 (m, 2H), 7.79–7.90 (m, 5H), 8.26 (s, 1H); (*minor* isomer) δ 4.79 (ddd, *J* = 5.7, 1.4, 1.4 Hz, 2H), 7.97–8.00 (m, 1H), 8.42 (s, 1H), the other peaks were not found probably due to overlapping.; $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 75.2, 117.9, 122.9, 126.5, 126.8, 127.8, 128.2, 128.3, 128.4, 129.9, 133.1, 134.0, 148.9, one peak was not found probably due to overlapping. (*minor* isomer) δ 75.8, 117.5, 126.3, 127.3, 127.4, 127.5, 127.9, 128.9, 131.5, 132.9, 133.6, 134.2, 146.1, one peak was not found probably due to overlapping; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{14}H_{14}NO$ 212.1075; Found 212.1070.

6-Methoxy-2-naphthaldehyde *O*-allyl oxime (**1m**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 95/5). White solid (650 mg, 2.69 mmol, 89% yield as a 97:3 mixture of stereoisomers); M.p. 79.2–80.6 ˚C; IR (KBr) 3064, 2942, 2867, 1625, 1270, 1119, 1047, 857, 817 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 3.91 (s, 3H), 4.71 (ddd, *J* = 5.9, 1.4, 1.4 Hz, 2H), 5.27 (ddt, *J* = 10.3, 1.6, 1.4 Hz, 1H), 5.38 (ddt, *J* = 17.4, 1.6, 1.4 Hz, 1H), 6.09 (ddt, *J* = 17.4, 10.3, 5.9 Hz, 1H), 7.11–7.17 (m, 2H), 7.70 (d, *J* = 7.8 Hz, 1H), 7.73 (d, *J* = 8.4 Hz, 1H), 7.79–7.83 (m, 2H), 8.23 (s, 1H); $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 55.3, 75.2, 106.0, 117.9, 119.2, 123.6, 127.3, 127.7, 128.1, 128.5, 129.8, 134.1, 135.4, 149.1, 158.4; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{15}H_{16}NO_2$ 242.1181; Found 242.1179.

1-Naphthaldehyde *O*-allyl oxime (**1n**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 97/3, 95/5). Colorless oil (598 mg, 2.83 mmol, 94% yield as a 95:5 mixture of stereoisomers); IR (neat) 3056, 2919, 2866, 1583, 1042, 799, 774 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 4.76–4.79 (m, 2H), 5.27–5.32 (m, 1H), 5.37–5.45 (m, 1H), 6.05–6.20 (m, 1H), 7.44–7.60 (m, 3H), 7.76 (d, *J* = 6.8 Hz, 1H), 7.85–7.89 (m, 2H), 8.55 (dd, *J* = 8.1, 0.81 Hz, 1H), 8.77 (s, 1H); (*minor* isomer) δ 4.68–4.71 (m, 2H), 7.98–8.05 (m, 2H), the other peaks were not found probably due to overlapping.; $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 75.2, 118.1, 124.5, 125.2, 126.1, 127.0, 127.4, 128.0, 128.7, 130.4, 130.6, 133.8, 134.1, 148.7; (*minor* isomer) δ 75.5, 117.6, 124.0, 125.0, 125.9, 126.6, 129.9, 134.2, 144.6, the other peaks were not found probably due to overlapping.; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{14}H_{14}NO$ 212.1075; Found 212.1070.

4-Methoxy-1-naphthaldehyde *O*-allyl oxime (**1o**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 97/3, 95/5). Yellow oil (649 mg, 2.69 mmol, 90% yield as a 97:3 mixture of stereoisomers); IR (neat) 3078, 2938, 2845, 1625, 1514, 1247, 1096, 1034 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 3.99 (s, 3H), 4.75 (ddd, *J* = 5.7, 1.5, 1.5 Hz, 2H), 5.25–5.31 (m, 1H), 5.41 (ddt, *J* = 17.2, 1.6, 1.5 Hz, 1H), 6.12 (ddt, *J* = 17.2, 10.4, 5.7 Hz, 1H), 6.78 (d, *J* = 8.0 Hz, 1H), 7.47–7.61 (m, 2H), 7.63 (d, *J* = 8.0 Hz, 1H), 8.29–8.33 (m, 1H), 8.62 (dd, *J* = 8.1, 1.1 Hz, 1H), 8.65 (s, 1H); (*minor* isomer) δ 4.70 (ddd, *J* = 5.4, 1.5, 1.5 Hz, 2H), 7.96–8.02 (m, 2H), 8.19 (d, *J* = 8.1, Hz, 1H), the other peaks were not found probably due to overlapping.; $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 55.6, 75.0, 103.3, 117.9, 120.6, 122.4, 124.7, 125.5, 125.7, 127.6, 128.9, 131.5, 134.2, 149.2, 157.0; (*minor* isomer) δ 75.4, 103.0, 117.4, 123.3, 125.2, 127.2, 143.9, the other peaks were not found probably due to overlapping; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{15}H_{16}NO_2$ 242.1181; Found 242.1181.

6-Methoxynicotinaldehyde *O*-allyl oxime (**1p**)

This compound was prepared according to the similar method to **1a** and the desired

product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 95/5, 9/1). Yellow oil (545 mg, 2.84 mmol, 95% yield as a 89:11 mixture of stereoisomers); IR (neat) 3081, 2949, 2850, 1615, 1497, 1289, 1022, 834 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 3.95 (s, 3H), 4.65 (ddd, *J* = 5.9, 1.5, 1.5 Hz, 2H), 5.22–5.27 (m, 1H), 5.34 (ddt, *J* = 17.2, 1.6, 1.5 Hz, 1H), 6.04 (ddt, *J* = 17.2, 10.4, 5.9 Hz, 1H), 6.73–6.77 (m, 1H), 7.93 (dd, *J* = 8.4, 2.2 Hz, 1H), 8.07 (s, 1H), 8.19 (d, *J* = 2.2 Hz, 1H); (*minor* isomer) δ 3.97 (s, 3H), 4.71 (ddd, *J* = 5.7, 1.4, 1.4 Hz, 2H), 7.24 (s, 1H), 8.24 (dd, *J* = 8.9, 2.2 Hz, 1H), 8.62 (d, *J* = 2.2 Hz, 1H), the other peaks were not found probably due to overlapping.; $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 53.4, 75.0, 111.3, 117.7, 121.7, 133.9, 135.5, 145.5, 146.7, 164.8; (*minor* isomer) δ 75.6, 110.4, 117.6, 120.7, 140.5, 142.9, 150.0, 164.1, the other peaks were not found probably due to overlapping.; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{10}H_{13}N_2O_2$ 193.0977; Found 193.0977.

1*H*-Indole-3-carbaldehyde *O*-allyl oxime (**1q**)

This compound was prepared according to the similar method to **1a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 85/15, 4/1, 75/25). White solid (579 mg, 2.89 mmol, 96% yield as a 4:1 mixture of stereoisomers); M.p. 50.0–51.4 ˚C; IR (KBr) 3266, 2984, 2871, 1658, 1610, 1444, 1029, 750 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 4.70–4.72 (m, 2H), 5.24–5.28 (m, 1H), 5.34–5.43 (m, 1H), 6.04–6.19 (m, 1H), 7.19–7.40 (m, 4H), 8.15–8.21 (m, 1H), 8.34 (brs, 1H), 8.34 (s, 1H); (*minor* isomer) δ 4.79 (ddd, *J* = 5.7, 1.3, 1.3 Hz, 2H), 7.75–7.79 (m, 2H), 8.53 (brs, 1H), the other peaks were not found probably due to overlapping.; $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 74.8, 110.0, 111.3, 117.9, 121.2, 122.1, 123.3, 124.4, 127.2, 134.3, 136.5, 144.8; (*minor* isomer) δ 75.2, 106.8, 111.4, 117.5, 118.0, 121.0, 122.8, 126.3, 130.7, 134.3, 134.7, 139.3; HRMS (ESI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{12}H_{13}N_2O$ 201.1028; Found 201.1028.

Preparation of benzaldehyde oxime (5)[21]

This compound was prepared according to the similar method to **1a** using hydroxylamine hydrochloride and the desired benzaldehyde oxime (**5**) was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 9/1) as a pale

yellow oil (421 mg, 3.47 mmol, 69% yield as a 94:6 mixture of stereoisomers). ^{1}H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 7.33–7.42 (m, 3H), 7.54–7.59 (m, 2H), 8.18 (s, 1H), 9.35 (brs, 1H); (*minor* isomer) δ 7.95–7.97 (m, 2H), the other peaks were not found probably due to overlapping.; ^{13}C{^{1}H} NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 127.0, 128.7, 130.0, 131.8, 150.4; (*minor* isomer) δ 128.4, 130.2, 130.9, 146.7, one peak was not found probably due to overlapping.; GC-MS (EI): *m*/*z* 121 $[M]^+$.

Preparation of benzaldehyde *O*-methyl oxime (6)[22]

This compound was prepared according to the similar method to **1a** using *O*-methylhydroxylamine hydrochloride and the desired benzaldehyde *O*-methyl oxime (**6**) was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 99.5/0.5) as a pale yellow oil (483 mg, 3.57 mmol, 36% yield as 96:4 mixture of stereoisomers). ^{1}H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 3.98 (s, 3H), 7.34–7.39 (m, 3H), 7.55–7.62 (m, 2H), 8.06 (s, 1H); (*minor* isomer) δ 4.03 (s, 3H), 7.85–7.89 (m, 2H), the other peaks were not found probably due to overlapping.; ^{13}C{^{1}H} NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 62.0, 127.0, 128.7, 129.8, 132.1, 148.6; GC-MS (EI): *m*/*z* 135 $[M]^+$.

Preparation of benzaldehyde *O*-but-3-en-1-yl oxime (3)

Benzaldehyde oxime (**5**) (848 mg, 7.0 mmol) was charged into a two-necked round flask and the flask was refilled with N_2. THF (25 mL) and potassium *tert*-butoxide 1.73 g, 15.4 mmol, 2.2 equiv) were added to the flask. A solution of but-3-en-1-yl 4-methylbenzenesulfonate (2.37 g, 10.5 mmol, 1.5 equiv) in THF (20 mL) was added dropwise to the mixture at room temperature. The reaction mixture was stirred overnight at 60 ˚C and then allowed to cool to room temperature. The reaction was quenched with H_2O (20 mL) and the resulting aqueous phase was extracted with Et_2O (40 mL × 3). The combined organic phase was washed with brine, dried over $MgSO_4$. After removal of the solvent, the resulting crude mixture was purified by silica gel column chromatography (Hexane/EtOAc = 99.5/0.5) to give benzaldehyde *O*-but-3-en-1-yl oxime (**3**) as a pale yellow oil (425 mg, 2.43 mmol, 35% yield as a 95:5 mixture of stereoisomers). IR (neat) 3079, 2931, 2876, 1642, 1447, 1211, 1051, 756, 692 cm^{-1}; ^{1}H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 2.49 (dtdd, *J* = 6.8, 6.6, 1.4, 1.4 Hz, 2H), 4.22 (t, *J* = 6.8 Hz, 2H), 5.05–5.18 (m, 2H), 5.87 (ddt, *J* = 17.3, 10.5, 6.6

Hz, 1H), 7.34–7.38 (m, 3H), 7.56–7.61 (m, 2H), 8.09 (s, 1H); (*minor* isomer) δ 4.27 (t, *J* = 6.8 Hz, 2H), 7.30 (s, 1H), 7.87–7.89 (m, 2H), the other peaks were not found probably due to overlapping.; $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 33.6, 73.3, 116.6, 126.9, 128.6, 129.6, 132.3, 134.7, 148.4; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{11}H_{14}NO$ 176.1075; Found 176.1084.

Preparation of benzaldehyde *O*-pent-4-en-1-yl oxime (4)

This compound was prepared according to the similar method to **3** using pent-4-en-1-yl 4-methylbenzenesulfonate and the desired benzaldehyde *O*-pent-4-en-1-yl oxime (**4**) was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 99.5/0.5) as a yellow oil (188 mg, 0.992 mmol, 15% yield as a 95:5 mixture of stereoisomers). IR (neat) 3079, 2934, 2872, 1640, 1447, 1211, 1055, 755, 692 cm^{-1}; ^{1}H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 1.77–1.87 (m, 2H), 2.14–2.22 (m, 2H), 4.19 (t, *J* = 6.6 Hz, 2H), 4.96–5.10 (m, 2H), 5.85 (ddt, *J* = 17.0, 10.3, 6.7 Hz, 1H), 7.34–7.42 (m, 3H), 7.55–7.60 (m, 2H), 8.08 (s, 1H); (*minor* isomer) δ 4.24 (t, *J* = 7.3 Hz, 2H), 7.30 (s, 1H), 7.88–7.91 (m, 2H), the other peaks were not found probably due to overlapping.; $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 28.3, 30.0, 73.6, 114.9, 126.9, 128.6, 129.7, 132.4, 138.1, 148.3; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{12}H_{16}NO$ 190.1232; Found 190.1227.

Preparation of benzaldehyde *O*-(1-phenylallyl) oxime (7)[23]

1-Phenylallyl acetate (881 mg, 5.0 mmol), benzaldehyde oxime **5** (727 mg, 6.0 mmol, 1.2 equiv), and $[IrCl(cod)]_2$ (16.8 mg, 0.025 mmol 0.005 equiv) were charged into a two-necked round flask and the flask was refilled with N_2. THF (20 mL) was added to the flask. Et_2Zn (1.09 M in hexane, 2.8 mL, 3.0 mmol 0.6 equiv) was added dropwise to the mixture at 0 ˚C. The reaction mixture was stirred at room temperature overnight. The reaction was quenched with H_2O (10 mL) and the resulting aqueous phase was extracted with EtOAc (20 mL × 3). The combined organic phase was washed with brine, dried over $MgSO_4$. After removal of the solvent, the resulting crude mixture was purified by silica gel column chromatography (Hexane/EtOAc = 99/1, 99/3) to give *O*-(1-phenylallyl) oxime (**7**) as a pale yellow oil (549 mg, 2.31 mmol, 50% yield as a 99:1 mixture of branch and linear regioisomers. The branch regioisomer was obtained as a 95:5 mixture of stereoisomers). ^{1}H NMR (270 MHz, $CDCl_3$): (*major* isomer)

δ 5.27–5.36 (m, 2H), 5.71 (d, *J* = 6.5, 1H), 6.16 (ddd, *J* = 17.1, 10.5, 6.5 Hz, 1H), 7.26–7.43 (m, 8H), 7.52–7.57 (m, 2H), 8.18 (s, 1H); (*minor* isomer) δ 7.92–7.96 (m, 2H), the other peaks were not found probably due to overlapping.; $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 86.1, 117.3, 127.1, 127.3, 127.8, 128.4, 128.6, 129.8, 132.2, 137.6, 140.1, 149.1; LRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ 238.

Preparation of (*E*)-cinnamaldehyde *O*-allyl oxime (8a)

Sodium acetate (369 mg, 4.5 mmol, 1.5 equiv) and *O*-allylhydroxylamine hydrochloride (394 mg, 3.6 mmol 1.2 equiv) were charged into a round flask. After the addition of MeOH (8.3 mL) and H_2O (0.75 mL) into the flask, cinnamaldehyde (0.38 mL, 3.0 mmol) was added dropwise to the mixture at room temperature. The reaction mixture was stirred at room temperature overnight. The resulting mixture was concentrated by evaporation and then H_2O was added. The resulting aqueous phase was extracted with EtOAc (12 mL × 3). The combined organic phase was washed with brine, dried over $MgSO_4$. After removal of the solvent, the resulting crude mixture was purified by silica gel column chromatography (Hexane/EtOAc = 98/2, 95/5) to give (*E*)-cinnamaldehyde *O*-allyl oxime (**8a**) as a pale yellow oil (537 mg, 2.87 mmol, 96% yield as a 74:26 mixture of stereoisomers). IR (neat) 3081, 2920, 2867, 1626, 1027, 974, 750 cm^{-1}; ^{1}H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 4.62 (ddd, *J* = 5.9 1.4, 1.4 Hz, 2H), 5.26 (ddt, *J* = 10.3, 1.5, 1.4 Hz, 1H), 5.34 (ddt, *J* = 17.2, 1.5, 1.4 Hz, 1H), 6.03 (ddt, *J* = 17.2, 10.3, 5.9 Hz, 1H), 6.75–6.90 (m, 1H), 7.19–7.52 (m, 6H), 7.92 (dd, *J* = 8.1, 1.1 Hz, 1H); (*minor* isomer) δ 4.66 (ddd, *J* = 5.9, 1.4, 1.4 Hz, 2H), the other peaks were not found probably due to overlapping.; $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 75.0, 116.3, 117.9, 121.9, 126.8, 128.7, 133.9, 135.9, 138.5, 150.8; (*minor* isomer) δ 75.2, 117.6, 127.4, 129.2, 134.3, 135.8, 139.8, 148.2, the other peaks were not found probably due to overlapping.; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{12}H_{14}NO$ 188.1075; Found 188.1070.

(*E*)-3-(4-(Dimethylamino)phenyl)acrylaldehyde *O*-allyl oxime (**8b**)

This compound was prepared according to the similar method to **8a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 95/5, 9/1, 85/15). Yellow solid (602 mg, 2.61 mmol, 87% yield as a

71:29 mixture of stereoisomers); M.p. 47.8–50.9 ˚C; IR (KBr) 3077, 2911, 1606, 1032, 981, 840 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 2.99 (s, 6H), 4.59 (ddd, *J* = 5.9, 1.5, 1.5 Hz, 2H), 5.24 (ddt, *J* = 10.3, 1.7, 1.5 Hz, 1H), 5.34 (ddt, *J* = 17.2, 1.7, 1.5 Hz, 1H), 5.95–6.11 (m, 1H), 6.59–6.79 (m, 4H), 7.08–7.41 (m, 2H), 7.89 (dd, *J* = 8.5, 0.68 Hz, 1H); (*minor* isomer) δ 3.00 (s, 6H), 4.64 (ddd, *J* = 5.7, 1.4, 1.4 Hz, 2H), the other peaks were not found probably due to overlapping.; $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 40.2, 74.7, 112.0, 117.0, 117.7, 124.1, 128.1, 134.1, 139.1, 150.7, 151.7; (*minor* isomer) δ 40.1, 74.9, 111.8, 111.9, 117.3, 123.7, 128.9, 134.5, 140.6, 149.2, 151.0; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{14}H_{19}N_2O$ 231.1497; Found 231.1497.

(*E*)-3-(4-Methoxyphenyl)acrylaldehyde *O*-allyl oxime (**8c**)

This compound was prepared according to the similar method to **8a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 95/5, 93/7, 9/1). White semi-solid (637 mg, 2.93 mmol, 95% yield as a 75:25 mixture of stereoisomers); IR (KBr) 2938, 2839, 1605, 1509, 1030, 973, 812 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 3.80 (s, 3H), 4.60 (ddd, *J* = 5.7, 1.4, 1.4 Hz, 2H), 5.22–5.26 (m, 1H), 5.33 (ddt, *J* = 17.4, 1.8, 1.4 Hz, 1H), 5.95–6.09 (m, 1H), 6.64–6.80 (m, 1H), 6.85–6.88 (m, 2H), 7.15–7.45 (m, 3H), 7.89 (dd, *J* = 5.9, 3.2 Hz, 1H); (*minor* isomer) δ 4.65 (ddd, *J* = 5.9, 1.4, 1.4 Hz, 2H), the other peaks were not found probably due to overlapping.; $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 55.2, 74.9, 114.2, 117.8, 119.6, 128.2, 128.9, 134.0, 138.2, 151.1, 160.1; (*minor* isomer) δ 75.0, 114.2, 117.5, 128.5, 128.7, 134.4, 139.6, 148.5, 160.5, the other peaks were not found probably due to overlapping.; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{13}H_{16}NO_2$ 218.1181; Found 218.1184.

(*E*)-3-(4-Fluorophenyl)acrylaldehyde *O*-allyl oxime (**8d**)

This compound was prepared according to the similar method to **8a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 95/5). Yellow oil (543 mg, 2.65 mmol, 88% yield as a 75:25 mixture of stereoisomers); IR (neat) 3080, 2922, 2868, 1626, 1601, 1508, 1232, 1028, 819 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 4.62 (ddd, *J* = 5.8, 1.4, 1.4 Hz, 2H), 5.26 (ddt, *J* = 10.5, 1.6, 1.4 Hz, 1H), 5.34 (ddt, *J* = 17.3, 1.6, 1.4 Hz, 1H), 6.02 (ddt, *J* = 17.3,

10.5, 5.8 Hz, 1H), 6.75–6.83 (m, 1H), 7.00–7.11 (m, 2H), 7.17–7.51 (m, 3H), 7.89–7.92 (m, 1H); (*minor* isomer) δ 4.66 (ddd, *J* = 5.7, 1.4, 1.4 Hz, 2H), the other peaks were not found probably due to overlapping.; $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 75.0, 115.7 (d, J_{CF} = 21.7 Hz), 117.8, 121.6 (d, J_{CF} = 2.2 Hz), 128.4 (d, J_{CF} = 8.3 Hz), 132.1 (d, J_{CF} = 3.3 Hz), 133.9, 137.0, 150.5, 162.8 (d, J_{CF} = 249 Hz); (*minor* isomer) δ 75.1, 116.0 (d, J_{CF} = 2.2 Hz), 117.6, 129.1 (d, J_{CF} = 8.3 Hz), 132.0 (d, J_{CF} = 3.3 Hz), 134.0 (d, J_{CF} = 21.2 Hz), 138.4, 147.9, 163.1 (d, J_{CF} = 249 Hz), one peak was not found probably due to overlapping.; ^{19}F NMR (471 MHz, $CDCl_3$): (*major* isomer) δ -113.0 – -113.1 (m); (*minor* isomer) δ -112.17 – -112.23 (m); HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{12}H_{13}FNO$ 206.0981; Found 206.0973.

4-((*E*)-3-((Allyloxy)imino)prop-1-en-1-yl)-2-methoxyphenyl acetate (**8e**)

This compound was prepared according to the similar method to **8a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 95/5, 9/1, 85/15, 4/1). Pale yellow oil (315 mg, 1.14 mmol, 38% yield as a 72:28 mixture of stereoisomers); M.p. 96.7‑99.3 ˚C; IR (KBr) 3010, 2925, 2874, 1762, 1629, 1599, 1013, 828 cm^{-1}; ^{1}H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 2.32 (s, 3H), 3.85 (s, 3H), 4.62 (ddd, *J* = 5.7, 1.3, 1.3 Hz, 2H), 5.26 (ddt, *J* = 10.5, 1.6, 1.3 Hz, 1H), 5.35 (ddt, *J* = 17.2, 1.6, 1.3 Hz, 1H), 5.95–6.11 (m, 1H), 6.72–6.86 (m, 2H), 7.01–7.33 (m, 3H), 7.91 (dd, *J* = 7.2, 2.0 Hz, 1H); (*minor* isomer) δ 3.87 (s, 3H), 4.67 (ddd, *J* = 5.4, 1.4, 1.4 Hz, 2H), the other peaks were not found probably due to overlapping.; $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 20.6, 55.7, 75.0, 109.9, 117.9, 119.9, 122.1, 123.0, 133.9, 134.9, 137.6, 140.1, 150.5, 151.2, 168.8; (*minor* isomer) δ 55.8, 75.2, 110.5, 116.3, 117.7, 120.6, 134.2, 134.7, 139.2, 140.6, 147.9, 151.2, 168.8, the other peaks were not found probably due to overlapping.; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{15}H_{18}NO_4$ 276.1236; Found 276.1232.

(*E*)-3-(Furan-2-yl)acrylaldehyde *O*-allyl oxime (**8f**)

This compound was prepared according to the similar method to **8a** using and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 95/5, 9/1). Reddish brown oil (483 mg, 2.72 mmol, 90% yield as a 72:28 mixture of stereoisomers); IR (neat) 3082, 2921, 2867, 1630, 1015, 740 cm^{-1}; ^{1}H

NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 4.61 (ddd, *J* = 5.8, 1.4, 1.4 Hz, 2H), 5.25 (ddt, *J* = 10.3, 1.4, 1.4 Hz, 1H), 5.33 (ddt, *J* = 17.1, 1.4, 1.4 Hz, 1H), 6.02 (ddt, *J* = 17.1, 10.3, 5.8 Hz, 1H), 6.40–6.78 (m, 4H), 7.42–7.45 (m, 1H), 7.85 (d, *J* = 9.7 Hz, 1H); (*minor* isomer) δ 4.66 (ddd, *J* = 5.4, 1.3, 1.3 Hz, 2H), 7.13–7.25 (m, 2H), the other peaks were not found probably due to overlapping.; $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 75.0, 110.8, 111.8, 117.9, 120.2, 125.4, 133.9, 143.3, 150.4, 152.1; (*minor* isomer) δ 75.2, 112.0, 112.3, 114.5, 117.5, 126.3, 134.3, 143.8, 147.8, 152.0; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{10}H_{12}NO_2$ 178.0868; Found 178.0866.

(*E*)-2-Methyl-3-phenylacrylaldehyde *O*-allyl oxime (**8g**)

This compound was prepared according to the similar method to **8a** using and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 98/2, 95/5). Yellow oil (579 mg, 2.88 mmol, 96% yield); IR (neat) 3082, 2921, 2865, 1646, 1601, 1050, 752 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): δ 2.11 (d, *J* = 1.4 Hz, 3H), 4.63 (ddd, *J* = 5.9, 1.5, 1.5 Hz, 2H), 5.22–5.27 (m, 1H), 5.34 (ddt, *J* = 17.0, 1.6, 1.5 Hz, 1H), 5.97–6.11 (m, 1H), 6.63 (s, 1H), 7.25–7.32 (m, 1H), 7.34–7.40 (m, 4H), 7.89 (s, 1H); $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): δ 13.1, 75.0, 117.8, 127.4, 128.3, 129.3, 132.2, 134.1, 136.1, 136.5, 153.9; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{13}H_{16}NO$ 202.1232; Found 202.1236.

3,3-Diphenylacrylaldehyde *O*-allyl oxime (**8h**)

This compound was prepared according to the similar method to **8a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 98/2, 95/5). Colorless oil (758 mg, 2.88 mmol, 95% yield as a 76:24 mixture of stereoisomers); IR (neat) 3058, 2920, 2866, 1646, 1606, 1076, 768 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): (*major* isomer) δ 4.59 (ddd, *J* = 5.9, 1.5, 1.5 Hz, 2H), 5.21–5.27 (m, 1H), 5.31 (ddt, *J* = 17.2, 1.8, 1.5 Hz, 1H), 5.92–6.12 (m, 1H), 6.79 (d, *J* = 10.4 Hz, 1H), 7.19–7.43 (m, 10H), 7.79 (d, *J* = 10.4 Hz, 1H); (*minor* isomer) δ 4.66 (ddd, *J* = 5.7, 1.4, 1.4 Hz, 2H), 7.11 (d, *J* = 9.5 Hz, 1H), the other peaks were not found probably due to overlapping.; $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): (*major* isomer) δ 75.0, 118.0, 120.3, 127.7, 128.1, 128.3 (2C), 128.4, 130.1, 133.8, 138.3, 140.9, 149.2, 149.7; (*minor* isomer) δ 75.2, 114.7, 117.6, 128.2, 128.3, 128.4,

128.8, 130.4, 134.3, 138.0, 141.0, 146.3, 150.7, one peak was not found probably due to overlapping.; HRMS (APCI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{18}H_{18}NO$ 264.1388; Found 264.1381.

Procedure for the nickel-catalyzed transformation of alkene-tethered oxime ether 1a to benzonitrile (2a) by a traceless directing group strategy

Benzaldehyde *O*-allyl oxime (**1a**) (48.4 mg, 0.30 mmol) and DPEphos (16.2 mg, 0.03 mmol, 0.1 equiv) were charged into a screw cap vial and the vial was taken into a glove box. In the glove box, $Ni(cod)_2$ (8.3 mg, 0.03 mmol, 0.1 equiv) and THF (1.2 mL) were added to the vial and the reaction vial was taken from the glove box. The resulting mixture was stirred at 60 ˚C for 17 h. The reaction mixture was allowed to cool to room temperature and octane (34.3 mg, 0.30 mmol) was added to the mixture as an internal standard. After filtration of the mixture with a pad of celite, the yield of benzonitrile (**2a**) was determined to be 98% by GC analyses.

Procedure for the nickel-catalyzed transformation of alkene-tethered oxime ethers 1 to benzonitriles 2 by a traceless directing group strategy

4-Methoxybenzaldehyde *O*-allyl oxime (**1b**) (115 mg, 0.60 mmol) and DPEphos (32.3 mg, 0.06 mmol, 0.1 equiv) were charged into a screw vial and the vial was taken into a glove box. In the glove box, $Ni(cod)_2$ (16.5 mg, 0.06 mmol, 0.1 equiv) and THF (2.4 mL) were added to the vial and the reaction vial was taken from the glove box. The resulting mixture was stirred at 60 ˚C for 17 h. The reaction was allowed to cool to room temperature and then quenched with water (1 mL). The reaction mixture was filtrated with a pad of celite and additional water was added. The resulting aqueous phase was extracted with EtOAc. The organic phase was washed with brine and dried over $MgSO_4$. After removal of the solvent, the resulting crude mixture was purified by silica gel column chromatography (Hexane/EtOAc = 95/5) to give 4-methoxybenzonitrile (**2b**)[24] as a white solid (67.8 mg, 0.509 mmol, 85% yield). When the reaction was conducted on a 3.0 mmol scale the desired product **2b** was obtained in 89% yield (354 mg, 2.66 mmol). ^1H NMR (270 MHz, $CDCl_3$): δ 3.86 (s, 3H), 6.93–6.98 (m, 2H), 7.57–7.62 (m, 2H); $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): δ 55.5, 103.9, 114.7, 119.2, 134.0, 162.8; GC-MS (EI): *m*/*z* 133 $[M]^+$.

Benzo[*d*][1,3]dioxole-5-carbonitrile (**2c**)[25]

This compound was prepared according to the procedure to **2b** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 99/1, 98/2, 96/4). White solid (78.8 mg, 0.536 mmol, 90% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 6.08 (s, 2H), 6.87 (d, *J* = 8.0 Hz, 1H), 7.04 (d, *J* = 1.5 Hz, 1H), 7.22 (dd, *J* = 8.0, 1.5 Hz, 1H); ^{13}C{^{1}H} NMR (67.8 MHz, $CDCl_3$): δ 102.2, 104.8, 109.1, 111.3, 118.8, 128.2, 148.0, 151.5; GC-MS (EI): *m*/*z* 146 $[M-H]^+$.

3,4-Dimethoxybenzonitrile (**2d**)[24]

3,4-Dimethoxybenzaldehyde *O*-allyl oxime (**1d**) (133 mg, 0.60 mmol) and DPEphos (32.3 mg, 0.06 mmol, 0.1 equiv) were charged into a screw vial and the vial was taken into a glove box. In the glove box, $Ni(cod)_2$ (16.5 mg, 0.06 mmol, 0.1 equiv) and 1,4-dioxane (2.4 mL) were added to the vial and the reaction vial was taken from the glove box. The resulting mixture was stirred at 80 ˚C for 17 h. The reaction was allowed to cool to room temperature and then quenched with water (1 mL). The reaction mixture was filtrated with a pad of celite and additional water was added. The resulting aqueous phase was extracted with EtOAc. The organic phase was washed with brine and dried over $MgSO_4$. After removal of the solvent, the resulting crude mixture was dissolved in MeOH (1 mL) and $NaBH_3CN$ (18.9 mg, 0.30 mmol) was added to the mixture for removing the trace amount of 3,4-dimethoxybenzaldehyde generated during the catalysis. The reaction mixture was stirred at room temperature for 1 h and then concentrated by evaporation. Water (1 mL) was added to the resulting mixture and the aqueous phase was extracted with EtOAc (2 mL × 1). The organic phase was washed with brine and dried over $MgSO_4$. After removal of the solvent, the resulting crude mixture was purified by silica gel column chromatography (Hexane/EtOAc = 9/1, 85/15, 4/1) to give 3,4-dimethoxy benzonitrile (**2d**) as a pale yellow solid (75.9 mg, 0.465 mmol, 77% yield). ^{1}H NMR (270 MHz, $CDCl_3$): δ 3.91 (s, 3H), 3.94 (s, 3H), 6.91 (d, *J* = 8.4 Hz, 1H), 7.08 (d, *J* = 1.9 Hz, 1H), 7.29 (dd, *J* = 8.4, 1.9 Hz, 1H); ^{13}C{^{1}H} NMR (67.8 MHz, $CDCl_3$): δ 56.0, 56.1, 103.8, 111.2, 113.8, 119.2, 126.4, 149.1, 152.8; GC-MS (EI): *m*/*z* 163 $[M]^+$.

Terephthalonitrile (**2e**)[26]

This compound was prepared according to the procedure to **2d** (THF was used instead of 1,4-dioxane at 60 ˚C) and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 95/5, 9/1, 4/1). White solid (54.7 mg, 0.427 mmol, 71% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 7.80 (s, 4H); $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): δ 116.7, 117.0, 132.8; GC-MS (EI): *m*/*z* 128 $[M]^+$.

Methyl 4-cyanobenzoate (**2f**)[24]

This compound was prepared according to the procedure to **2d** (THF was used instead of 1,4-dioxane at 60 ˚C) and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 98/2, 96/4, 9/1). White solid (71.0 mg, 0.441 mmol, 74% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 3.97 (s, 3H), 7.73–7.77 (m, 2H), 8.13–8.17 (m, 2H); $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): δ 52.6, 116.2, 117.9, 130.0, 132.1, 133.8, 165.3; GC-MS (EI): *m*/*z* 161 $[M]^+$.

[1,1'-Biphenyl]-4-carbonitrile (**2g**)[24]

This compound was prepared according to the procedure to **2d** (PPh_3 (20 mol%) and THF were used instead of DPEphos and 1,4-dioxane, respectively, at 60 ˚C) and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 99/1, 98/2, 9/1) and preparative thin-layer chromatography (Hexane/EtOAc = 9/1). White solid (83.1 mg, 0.464 mmol, 77% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 7.38–7.51 (m, 3H), 7.55–7.60 (m, 2H), 7.64–7.72 (m, 4H); $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): δ 110.8, 118.9, 127.1, 127.6, 128.6, 129.0, 132.5, 139.1, 145.6; GC-MS (EI): *m*/*z* 179 $[M]^+$.

3-Methoxybenzonitrile (**2h**)[24]

This compound was prepared according to the procedure to **2d** (THF was used instead of 1,4-dioxane at 60 ˚C) and the desired product was obtained after purification by preparative thin-layer chromatography (Hexane/EtOAc = 9/1). Pale yellow oil (45.4 mg, 0.341 mmol, 57% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 3.83 (s, 3H), 7.11–7.16 (m, 2H), 7.22–7.25 (m, 1H), 7.35–7.41 (m, 1H); $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): δ 55.4, 113.0, 116.7, 118.6, 119.2, 124.3, 130.2, 159.5; GC-MS (EI): *m*/*z* 133 $[M]^+$.

3,5-Dimethoxybenzonitrile (**2i**)[26]

This compound was prepared according to the procedure to **2d** (THF was used instead of 1,4-dioxane at 60 ˚C) and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 98/2, 95/5, 9/1). White solid (79.8 mg, 0.489 mmol, 82% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 3.81 (s, 6H), 6.66 (t, *J* = 2.3 Hz, 1H), 6.76 (d, *J* = 2.4 Hz, 2H); $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): δ 55.5, 105.5, 109.8, 113.3, 118.7, 160.9; GC-MS (EI): *m*/*z* 163 $[M]^+$.

Isophthalonitrile (**2j**)[27]

This compound was prepared according to the procedure to **2d** (THF was used instead of 1,4-dioxane at 60 ˚C) and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 9/1, 85/15, 4/1). White solid (45.5 mg, 0.355 mmol, 59% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 7.64–7.70 (m, 1H), 7.90–7.98 (m, 3H); $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): δ 114.1, 116.5, 130.3, 135.3, 135.9; GC-MS (EI): *m*/*z* 128 $[M]^+$.

2-Methoxybenzonitrile (**2k**)[24]

This compound was prepared according to the procedure to **2b** (1,4-dioxane was used instead of THF at 100 ˚C) and the desired product was obtained after purification by preparative thin-layer chromatography (Hexane/EtOAc = 4/1). Yellow oil (45.6 mg, 0.342 mmol, 57% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 3.94 (s, 3H), 6.96–7.04 (m, 2H), 7.51–7.58 (m, 2H); $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): δ 55.9, 101.6, 111.2, 116.4, 120.7, 133.6, 134.3, 161.1; GC-MS (EI): *m*/*z* 133 $[M]^+$.

2-Naphthonitrile (**2l**)[24]

This compound was prepared according to the procedure to **2d** (PPh_3 (20 mol%) and THF were used instead of DPEphos and 1,4-dioxane, respectively, at 60 ˚C) and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 99/1, 98/2, 9/1) and preparative thin-layer chromatography (Hexane/EtOAc = 9/1). White solid (58.4 mg, 0.381 mmol, 64% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 7.54–7.66 (m, 3H), 7.83–7.89 (m, 3H), 8.17 (s, 1H); $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): δ 109.2, 119.1, 126.2, 127.5, 127.9, 128.3, 128.9, 129.1, 132.1, 134.0, 134.5; GC-MS (EI): *m*/*z* 153 $[M]^+$.

6-Methoxy-2-naphthonitrile (**2m**)[25]

This compound was prepared according to the procedure to **2b** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 98/2, 96/4, 94/6, 9/1). White solid (104 mg, 0.566 mmol, 94% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 3.95 (s, 3H), 7.14 (d, *J* = 2.3 Hz, 1H), 7.24 (dd, *J* = 8.9, 2.3 Hz, 1H), 7.55 (dd, *J* = 8.2, 1.8 Hz, 1H), 7.76 (d, *J* = 1.9 Hz, 1H), 7.79 (s, 1H), 8.12 (s, 1H); ^{13}C{^{1}H} NMR (67.8 MHz, $CDCl_3$): δ 55.4, 105.8, 106.6, 119.5, 120.6, 127.0, 127.6, 127.7, 129.9, 133.7, 136.3, 159.9; GC-MS (EI): *m*/*z* 183 $[M]^+$.

1-Naphthonitrile (**2n**)[24]

This compound was prepared according to the procedure to **2d** (PPh_3 (20 mol%) and THF were used instead of DPEphos and 1,4-dioxane, respectively, at 60 ˚C) and the desired product was obtained after purification by preparative thin-layer chromatography (Hexane/EtOAc = 9/1). Pale yellow oil (75.2 mg, 0.491 mmol, 82% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 7.47–7.55 (m, 1H), 7.57–7.72 (m, 2H), 7.87–7.92 (m, 2H), 8.04–8.09 (m, 1H), 8.20–8.25 (m, 1H); ^{13}C{^{1}H} NMR (67.8 MHz, $CDCl_3$): δ 110.0, 117.7, 124.8, 125.0, 127.4, 128.5(2C), 132.2, 132.5, 132.8, 133.2; GC-MS (EI): *m*/*z* 153 $[M]^+$.

4-Methoxy-1-naphthonitrile (**2o**)[24]

This compound was prepared according to the procedure to **2b** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 98/2, 96/4, 94/6, 9/1). White solid (103 mg, 0.562 mmol, 94% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 4.06 (s, 3H), 6.82 (d, *J* = 8.0 Hz, 1H), 7.55–7.61 (m, 1H), 7.66–7.72 (m, 1H), 7.85 (d, *J* = 8.0 Hz, 1H), 8.16 (d, *J* = 8.1 Hz, 1H), 8.31 (dd, *J* = 8.0, 0.95 Hz, 1H); ^{13}C{^{1}H} NMR (67.8 MHz, $CDCl_3$): δ 55.9, 101.7, 103.2, 118.4, 122.7, 124.8, 125.1, 126.6, 128.8, 133.3, 134.0, 159.3; GC-MS (EI): *m*/*z* 183 $[M]^+$.

6-Methoxynicotinonitrile (**2p**)[28]

This compound was prepared according to the procedure to **2d** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 98/2, 96/4, 92/8). White solid (53.4 mg, 0.398 mmol, 66% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 4.00 (s, 3H), 6.83 (dd, *J* = 8.6, 0.81 Hz, 1H), 7.79 (dd, *J* = 8.6, 2.3 Hz, 1H),

8.495–8.503 (m, 1H); $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): δ 54.2, 102.3, 111.7, 117.2, 140.8, 151.9, 165.9; GC-MS (EI): *m*/*z* 133 $[M-H]^+$.

1*H*-Indole-3-carbonitrile (**2q**)[29]

This compound was prepared according to the procedure to **2b** (1,4-dioxane was used instead of THF at 100 ˚C for 48 h) and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 9/1, 85/15, 4/1) and preparative thin-layer chromatography (Toluene/EtOAc = 9/1). Pale yellow solid (39.2 mg, 0.276 mmol, 46% yield); ^{1}H NMR (270 MHz, Acetone-d_6): δ 7.25–7.35 (m, 2H), 7.59–7.62 (m, 1H), 7.69–7.72 (m, 1H), 8.11 (d, *J* = 3.0 Hz, 1H), 11.2 (brs, 1H); $^{13}C\{^{1}H\}$ NMR (67.8 MHz, Acetone-d_6): δ 86.7, 113.5, 116.4, 119.5, 122.6, 124.4, 128.0, 134.2, 136.4; GC-MS (EI): *m*/*z* 142 $[M]^+$.

Procedure for the nickel-catalyzed transformation of alkene-tethered oxime ethers 8 to cinnamonitriles 9 by a traceless directing group strategy

(*E*)-Cinnamaldehyde *O*-allyl oxime (**8a**) (112 mg, 0.60 mmol) and DPEphos (64.6 mg, 0.12 mmol, 0.2 equiv) were charged into a screw vial and the vial was taken into a glove box. In the glove box, $Ni(cod)_2$ (33.0 mg, 0.12 mmol, 0.2 equiv) and 1,4-dioxane (2.4 mL) were added to the vial and the reaction vial was taken from the glove box. The resulting mixture was stirred at 100 ˚C for 17 h. The reaction was allowed to cool to room temperature and then quenched with water (1 mL). The reaction mixture was filtrated with a pad of celite and additional water was added. The resulting aqueous phase was extracted with EtOAc. The organic phase was washed with brine and dried over $MgSO_4$. After removal of the solvent, the resulting crude mixture was purified by silica gel column chromatography (Hexane/EtOAc = 98/2, 96/4, 94/6) to give cinnamonitrile (**9a**)[30] as a yellow oil (43.9 mg, 0.340 mmol, 57% yield). ^{1}H NMR (270 MHz, $CDCl_3$): δ 5.88 (d, *J* = 16.5 Hz, 1H), 7.38–7.48 (m, 6H); $^{13}C\{^{1}H\}$ NMR (67.8 MHz, $CDCl_3$): δ 96.3, 118.1, 127.3, 129.1, 131.2, 133.5, 150.6; GC-MS (EI): *m*/*z* 129 $[M]^+$.

(*E*)-3-(4-(Dimethylamino)phenyl)acrylonitrile (**9b**)

This compound was prepared according to the procedure to **9a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc =

98/2, 96/4, 9/1, 4/1). Yellow solid (65.2 mg, 0.379 mmol, 63% yield); M.p. 166.5-169.7 °C; IR (KBr) 3048, 2910, 2206, 1599, 972, 798 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): δ 3.03 (s, 6H), 5.57 (d, *J* = 16.5 Hz, 1H), 6.62–6.68 (m, 2H), 7.25–7.35 (m, 3H); $^{13}C\{^1H\}$ NMR (125.8 MHz, $CDCl_3$): δ 39.9, 89.1, 111.5, 119.7, 121.2, 128.9, 150.4, 152.0; HRMS (ESI/TOF) *m*/*z*: $[M+H]^+$ Calcd for $C_{11}H_{13}N_2$ 173.1079; Found 173.1081.

(*E*)-3-(4-Methoxyphenyl)acrylonitrile (**9c**)[30]

This compound was prepared according to the procedure to **9a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 98/2, 96/4, 94/6, 9/1) and preparative thin-layer chromatography (Hexane/EtOAc = 4/1). Yellow solid (64.1 mg, 0.403 mmol, 67% yield); ^1H NMR (270 MHz, $CDCl_3$): δ 3.85 (s, 3H), 5.71 (d, *J* = 16.6 Hz, 1H), 6.89–6.94 (m, 2H), 7.33 (d, *J* = 16.6 Hz, 1H), 7.37–7.43 (m, 2H); $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): δ 55.4, 93.3, 114.5, 118.7, 126.3, 129.0, 150.0, 162.0; GC-MS (EI): *m*/*z* 159 $[M]^+$.

(*E*)-3-(4-Fluorophenyl)acrylonitrile (**9d**)[30]

This compound was prepared according to the procedure to **9a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 99/1, 98/2, 96/4, 94/6). Pale yellow solid (54.8 mg, 0.372 mmol, 62% yield); ^1H NMR (270 MHz, $CDCl_3$): δ 5.81 (d, *J* = 16.7 Hz, 1H), 7.07–7.15 (m, 2H), 7.37 (d, *J* = 16.7 Hz, 1H), 7.42–7.49 (m, 2H); $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): δ 96.0 (d, J_{CF} = 2.8 Hz), 116.3 (d, J_{CF} = 21.8 Hz), 117.9, 129.3 (d, J_{CF} = 8.3 Hz), 129.8 (d, J_{CF} = 3.4 Hz), 149.2, 164.3 (d, J_{CF} = 253 Hz); ^{19}F NMR (471 MHz, $CDCl_3$): δ -108.7 – -108.8 (m); GC-MS (EI): *m*/*z* 147 $[M]^+$.

(*E*)-4-(2-Cyanovinyl)-2-methoxyphenyl acetate (**9e**)

This compound was prepared according to the procedure to **9a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 9/1, 85/15, 4/1). Pale yellow solid (81.4 mg, 0.375 mmol, 64% yield); M.p. 102.6-103.9 °C; IR (KBr) 3062, 2973, 2843, 2213, 1743, 1620, 1033, 822 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$): δ 2.33 (s, 3H), 3.86 (s, 3H), 5.83 (d, *J* = 16.6 Hz, 1H), 7.00 (d, *J* = 1.4 Hz, 1H), 7.03–7.10 (m, 2H), 7.36 (d, *J* = 16.6 Hz, 1H); $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): δ 20.5, 55.9, 96.5, 110.5, 117.9, 120.4, 123.4, 132.3, 142.1, 149.7, 151.5, 168.6; HRMS

(EI) *m*/*z*: $[M]^+$ Calcd for $C_{12}H_{11}NO_3$ 217.0739; Found 217.0735.

(*E*)-3-(Furan-2-yl)acrylonitrile (**9f**)[31]

This compound was prepared according to the procedure to **9a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 99/1, 98/2, 95/5). Reddish brown oil (36.1 mg, 0.303 mmol, 51% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 5.76 (d, *J* = 16.3 Hz, 1H), 6.50 (dd, *J* = 3.4, 1.6 Hz, 1H), 6.62 (d, *J* = 3.4 Hz, 1H), 7.11 (d, *J* = 16.3 Hz, 1H), 7.50 (d, *J* = 1.6 Hz, 1H); ^{13}C{^{1}H} NMR (67.8 MHz, $CDCl_3$): δ 93.3, 112.6, 115.4, 118.2, 136.1, 145.4, 149.7; GC-MS (EI): *m*/*z* 119 $[M]^+$.

(*E*)-2-Methyl-3-phenylacrylonitrile (**9g**)[32]

This compound was prepared according to the procedure to **9a** and the desired product was obtained after purification by silica gel column chromatography (Hexane/EtOAc = 95/5, 9/1). Pale yellow oil (66.6 mg, 0.465 mmol, 77% yield); ^{1}H NMR (270 MHz, $CDCl_3$): δ 2.15 (d, *J* = 1.4 Hz, 3H), 7.218–7.224 (m, 1H), 7.31–7.46 (m, 5H); ^{13}C{^{1}H} NMR (67.8 MHz, $CDCl_3$): δ 16.7, 109.5, 121.2, 128.6, 129.2 (2C), 134.0, 144.3; GC-MS (EI): *m*/*z* 143 $[M]^+$.

3,3-Diphenylacrylonitrile (**9h**)[33]

3,3-Diphenylacrylaldehyde *O*-allyl oxime (**8h**) (158 mg, 0.60 mmol) and DPEphos (64.6 mg, 0.12 mmol, 0.2 equiv) were charged into a screw vial and the vial was taken into a glove box. In the glove box, $Ni(cod)_2$ (33.0 mg, 0.12 mmol, 0.2 equiv) and 1,4-dioxane (2.4 mL) were added to the vial and the reaction vial was taken from the glove box. The resulting mixture was stirred at 100 ˚C for 17 h. The reaction was allowed to cool to room temperature and then quenched with water (1 mL). The reaction mixture was filtrated with a pad of celite and additional water was added. The resulting aqueous phase was extracted with EtOAc. The organic phase was washed with brine and dried over $MgSO_4$. After removal of the solvent, the resulting crude mixture was dissolved in MeOH (1 mL) and $NaBH_3CN$ (18.9 mg, 0.30 mmol) was added to the mixture for removing the trace amount of 3,3-diphenylacrylaldehyde generated during the catalysis. The reaction mixture was stirred at room temperature for 1 h and then concentrated by evaporation. Water (1 mL) was added to the resulting

mixture and the aqueous phase was extracted with EtOAc (2 mL × 1). The organic phase was washed with brine and dried over $MgSO_4$. After removal of the solvent, the resulting crude mixture was purified by silica gel column chromatography (Hexane/EtOAc = 99/1, 98/2) to give 3,3-diphenylacrylonitrile (**9h**) as a yellow oil (70.3 mg, 0.343 mmol, 57% yield). ^{1}H NMR (270 MHz, $CDCl_3$): δ 5.74 (s, 1H), 7.28–7.32 (m, 2H), 7.35–7.41 (m, 2H), 7.41–7.50 (m, 6H); $^{13}C\{^1H\}$ NMR (67.8 MHz, $CDCl_3$): δ 94.8, 117.8, 128.4, 128.5, 128.6, 129.5, 130.0, 130.3, 137.0, 138.8, 163.1; GC-MS (EI): *m*/*z* 205 $[M]^+$.

Experimental details for the control experiments

Transformation of benzaldehyde *O*-but-3-en-1-yl oxime (**3**) to benzonitrile (**2a**):
Benzaldehyde *O*-but-3-en-1-yl oxime (**3**) (52.6 mg, 0.30 mmol) and DPEphos (16.2 mg, 0.03 mmol, 0.1 equiv) were charged into a screw vial and the vial was taken into a glove box. In the glove box, $Ni(cod)_2$ (8.3 mg, 0.03 mmol, 0.1 equiv) and THF (1.2 mL) were added to the vial and the reaction vial was taken from the glove box. The resulting mixture was stirred at 60 ˚C for 17 h. The reaction mixture was allowed to cool to room temperature and octane (34.3 mg, 0.30 mmol) was added to the mixture as an internal standard. After filtration of the mixture with a pad of celite, the yield of benzonitrile (**2a**) was determined to be 7% by GC analyses.

Transformation of benzaldehyde *O*-pent-4-en-1-yl oxime (**4**) to benzonitrile (**2a**): This experiment was conducted according to the same procedure to **3** and the yield of benzonitrile (**2a**) was determined to be 34% by GC analyses.

Transformation of benzaldehyde oxime (**5**) to benzonitrile (**2a**): This experiment was conducted according to the same procedure to **3** and the yield of benzonitrile (**2a**) was determined to be 4% by GC analyses.

Transformation of benzaldehyde *O*-methyl oxime (**6**) to benzonitrile (**2a**): This experiment was conducted according to the same procedure to **3** and the yield of benzonitrile (**2a**) was determined to be 16% by GC analyses.

Transformation of benzaldehyde *O*-(1-phenylallyl) oxime (**7**) to benzonitrile (**2a**): This

experiment was conducted according to the same procedure to **3** and the yield of benzonitrile (**2a**), 1-phenyl-2-propen-1-ol, and propiophenone were determined to be 98%, 82%, and 1% yield, respectively, by GC analyses.

Supporting Information

The Supporting Information is available free of charge at

• GC spectrum for the determination of GC yield of **2a**, GC spectra for the control experiments, ^{1}H, ^{13}C{1H}, and ^{19}F NMR spectra for starting materials and products, and ^{1}H NMR spectra for **1a**, **5**, **6**, and **7**.

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