



Supporting Information

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Heterogeneously Catalyzed One-Pot Synthesis of Primary Amides from Aldoximes or Aldehydes in Water by Supported Rhodium Catalyst

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Experimental Section

Instrumentation: GC analyses were performed on Shimadzu GC-2014 with a FID detector equipped with a TC-1 or TC-5 capillary column. Mass spectra were recorded on Shimadzu GCMS-QP2010 at an ionization voltage of 70 eV. Liquid-state NMR spectra were recorded on JEOL JNM-EX-270. ^1H and ^{13}C NMR spectra were measured at 270 and 67.8 MHz, respectively, with TMS as an internal standard. ^2H NMR spectra were measured at 41.25 MHz using C_6D_6 as an external standard. The IR spectra were measured on JASCO FT/IR-460 Plus. ESR measurements (X-band) were performed with JEOL JES-RE-1X. XRD patterns were measured with Rigaku MultiFlex using Cu K α radiation (40 kV–50 mA). XPS measurements were carried out on JEOL JPS-90 using monochromated Al K α radiation ($h\nu=1486.6$ eV). The X-ray anode was run at 200 W and the voltage was kept at 10 kV. The pass energy was fixed at 10.0 eV to ensure sufficient resolution to determine peak positions accurately. The binding energies were calibrated by using the C 1s signal at 285.0 eV. ICP-AES analyses were performed with Shimadzu ICPS-8100.

Reagents: Alumina (KHS-24, BET surface area: $160 \text{ m}^2\cdot\text{g}^{-1}$) was supplied from Sumitomo Chemical Co., Ltd. Solvents, aldehydes, and **6a** were obtained from Tokyo Kasei or Aldrich (reagent grade) and purified prior to the use.^[17] $\text{RhCl}_3\cdot3\text{H}_2\text{O}$ were obtained from Wako (reagent grade) and used as received. $\text{NH}_2\text{OH}\cdot\text{HCl}$ and $(\text{NH}_2\text{OH})_2\cdot\text{H}_2\text{SO}_4$ were obtained from

Tokyo Kasei (reagent grade) and used as received. Benzaldehyde- α -d₁ was obtained from CDN isotopes (reagent grade) and used as received.

Synthesis of Aldoximes: Aldoximes were synthesized by the dehydrative condensation of the corresponding aldehydes with NH₂OH·HCl.^[18] A typical procedure was as follows: Into a glass flask were successively placed an aldehyde (10 mmol), NH₂OH·HCl (2–3 equiv. with respect to an aldehyde), ethanol (10 mL), and pyridine (1 mL). The reaction mixture was stirred at room temperature. After complete the reaction, ethanol was removed under reduced pressure on a rotary evaporator. Then, deionized water (ca. 10 mL) was added to the residue and the mixture was cooled in an ice-bath until the aldoxime crystallized out (For **3a**, **4a**, **5a**, and **12a**, aldoximes were extracted into dichloromethane and purified by Kugelrohr distillation.). The aldoxime was filtered, washed with deionized water (ca. 100 mL), dried, and recrystallized from ethanol. All aldoximes were confirmed by mass and NMR.^[18] The E/Z ratios of aldoximes are listed in Table S1.

α -Deutero-benzaldoxime: *E*>95%. MS (70 eV, EI): *m/z* (%): 122 (100) [M⁺], 121. (19), 104 (11), 103 (15), 94 (26), 78 (55), 77 (46), 76 (16), 66 (17), 51 (27), 50 (14). ¹H NMR (270 MHz, CDCl₃, 298 K, TMS): δ = 7.37–7.43 (m, 1H + 2H, ArH), 7.59–7.63 (m, 2H, ArH), 9.43 (brs, 1H, OH). ²H NMR (41.25 MHz, benzene, 298 K, C₆D₆): δ = 8.20 (s, 1D, CDNOH). ¹³C NMR (67.8 MHz, CDCl₃, 298 K, TMS): δ = 127.0, 128.8, 130.1, 131.0 (*Ar*), 150.2 (t, ¹J(C,D) = 25.7 Hz, CDNOH).

Dehydrative Condensation of Aldehydes with Hydroxylamine: Into a glass vial were successively placed Rh(OH)_x/Al₂O₃ (Rh: 2 mol%), NH₂OH·HCl (2 mmol), benzaldehyde (1 mmol), and *o*-xylene (3 mL). The reaction mixture was stirred at 80 °C under 1 atm of Ar. The conversion and yield were periodically determined by GC analysis. Reaction rates were determined from the slopes of reaction profiles ([benzaldehyde]₀–[benzaldehyde]_t vs. time plots) at low conversions (<10%) of benzaldehyde (initial rate method). The reaction rate of the dehydrative condensation of benzaldehyde and the hydroxylamine in the presence of

$\text{Rh(OH)}_x/\text{Al}_2\text{O}_3$ was $1.5 \text{ mM}\cdot\text{min}^{-1}$ and much faster than that ($0.035 \text{ mM}\cdot\text{min}^{-1}$) in the absence of the catalyst.

Synthesis of Amides from Aldehydes: A typical $\text{Rh(OH)}_x/\text{Al}_2\text{O}_3$ -catalyzed synthesis of amides from aldehydes was carried out as follows: *n*-Dodecanal (0.5 mmol), $\text{Rh(OH)}_x/\text{Al}_2\text{O}_3$ (Rh: 4 mol%), $(\text{NH}_2\text{OH})_2\cdot\text{H}_2\text{SO}_4$ (0.25 mmol, one equiv. with respect to aldehydes), and water (2 mL) were placed in a Teflon vessel with a magnetic stir bar. The Teflon vessel was attached inside an autoclave, and then the autoclave was heated at 120°C (bath temperature). After the reaction was finished, the spent catalyst was separated by filtration, washed with ethanol, and dried in *vacuo* prior to being recycled. The products were isolated by a silica gel column chromatography using ethanol as an eluent. All products were known and available. The products were confirmed by the comparison of their GC retention time, mass, and ^1H and ^{13}C NMR spectroscopy with those of authentic samples.

References

- [17] *Purification of Laboratory Chemicals*, 3rd ed., Perrin, D. D.; Armarego W. L. F. Eds.; Pergamon Press: Oxford, U.K., 1988.
- [18] N. Jain, A. Kumar, S. M. S. Chauhan, *Tetrahedron Lett.* **2005**, 46, 2599 and references cited therein.

Table S1: Synthesis of various amides from aldoximes by Rh(OH)_x/Al₂O₃.^[a]

Entry	Substrate ^[b]	Conv. of oxime [%]	Select. [%]			
			amide ^[c]	nitrile	aldehyde	acid
1	1a (<i>E/Z</i> = 54/46)	>99	93(84)	5	<1	2
2 ^[d]	1a (<i>E/Z</i> = 54/46)	>99	91	7	1	1
3	2a (<i>E/Z</i> = 59/41)	>99	98(83)	1	<1	<1
4	3a (<i>E/Z</i> = 55/45)	>99	99(86)	<1	1	<1
5	4a (<i>E/Z</i> = 67/33)	>99	96(86)	4	<1	<1
6	5a (<i>E/Z</i> = 72/28)	87	88(63)	8	4	<1
7	6a (<i>E</i> >95%)	>99	85(76)	8	7	<1
8 ^[d]	6a (<i>E</i> >95%)	94	81	8	11	<1
9	7a (<i>E</i> >95%)	>99	85(88)	5	10	<1
10	8a (<i>E</i> >95%)	>99	97(77)	1	2	<1
11	9a (<i>E</i> >95%)	>99	95(87)	1	4	<1
12	10a (<i>E</i> >95%)	>99	92(90)	<1	8	<1
13	11a (<i>E/Z</i> = 60/40)	>99	92(70)	6	2	<1
14	12a (<i>E/Z</i> = 53/47)	96	97(92)	3	<1	<1
15	13a (<i>E</i> >95%)	>99	96(84)	4	<1	<1
16	14a (<i>E/Z</i> = 36/64)	93	98(71)	1	1	<1

[a] Reaction conditions: Aldoxime (0.5 mmol), Rh(OH)_x/Al₂O₃ (Rh: 4 mol%), water (2 mL), 7 h. Conversion and selectivity were determined by GC analyses. [b] Values in the parentheses were isomer ratios of aldoximes. [c] Values in the parentheses were isolated yields. [d] Reuse experiment.

Table S2: Synthesis of various amides from aldehydes by Rh(OH)_x/Al₂O₃.^[a]

Entry	Substrate	Conv. of aldehyde [%]	Select. [%]			
			amide ^[b]	nitrile	oxime	acid
1 ^[c]	1c	>99	89(89)	5	<1	6
2	3c	>99	91(81)	2	2	5
3	7c	98	86(90)	5	<1	9
4	9c	98	94(85)	2	<1	4
5	11c	99	88(73)	9	<1	3
6	13c	99	99(85)	1	<1	<1

[a] Reaction conditions: Aldehyde (0.5 mmol), (NH₂OH)₂·H₂SO₄ (0.25 mmol, one equiv. with respect to aldehyde), Rh(OH)_x/Al₂O₃ (Rh: 4 mol%), water (2 mL), 7 h. [b] Values in the parentheses were isolated yields. [c] 9 h.

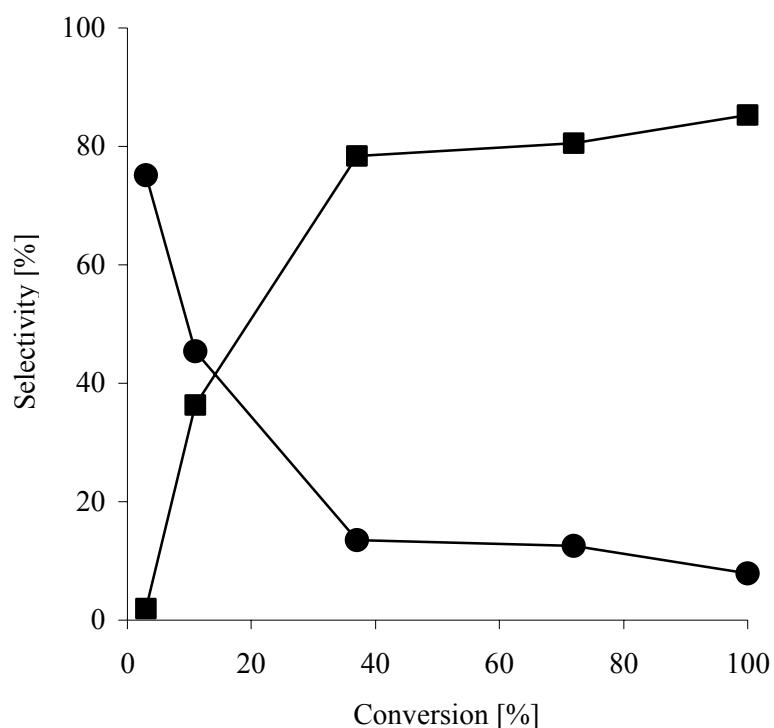


Figure S1: Conversion versus selectivity plots for the conversion of benzaldoxime to benzamide. Reaction conditions: Benzaldoxime (0.5 mmol), $\text{Rh(OH)}_x/\text{Al}_2\text{O}_3$ (Rh: 4 mol%), water (2 mL), 160 °C. Selectivities to benzamide (■) and benzonitrile (●).