

Supporting Information

High Yield One-Step Amination of Benzene to Aniline

Experimental:

General Considerations:

All reactions were performed on the bench top open to air. Iron(III) Oxide (99.9%) was acquired from Alfa Aesar. Sodium Metavanadate (96%) was purchased from Strem Chemicals. Hydroxylamine hydrochloride (99%) was obtained from Acros Organics and finely ground before use. All benzene and hydroxylamine derivatives were obtained commercially and used as-is. Catalysts V1-V4 were produced in-house following a procedure by Son and Toste.¹ Catalyst V5 was produced in-house following a procedure by Hanson *et. al.*² Hydroxylamine Hydrochloride is explosive when heated dry and highly toxic to both humans and the environment. All chemicals were used as is unless otherwise specified. GC and GCMS were performed on a GC-17A Limited Edition Shimadzu and a GCMS-QP5000 Shimadzu respectively. m-toluidine was used as an internal standard for all experiments unless otherwise indicated. Aniline was used as an internal standard for the production of toluidine.

Formation of Aniline From Benzene: Sodium metavanadate (0.0200 g, 0.162 mmol) and iron(III) oxide (0.0259 g, 0.162 mmol) were added to a round bottom flask equipped with a stir bar and reflux condenser. To the same flask were added trifluoroacetic acid (6 mL) and D.I. water (1.5 mL) creating a cloudy, dark red suspension upon stirring. Hydroxylamine hydrochloride (0.780 g, 11.2 mmol) was added to the above solution and stirred at 40 °C for 10 minutes. Benzene (4.00 mL, 44.9 mmol) was added and the combined solution was stirred at 100 °C for 5 hours, during which time the solution became clear green, then cloudy black with a green tinge. The solution was then cooled to room temperature and

neutralized with 30% w/w NaOH. The product was extracted with diethyl ether affording a clear red solution (94%). GC-MS (150 °C): 4.0 min, m/z = 78 (C₆H₆), 5.2 min, m/z = 94 (C₆H₇¹⁵N), 93 (C₆H₇¹⁴N), 6.0 min, m/z = 108 (C₇H₉¹⁵N), 107 (C₇H₉¹⁴N).

Formation of Toluidine From Toluene: Sodium metavanadate (0.0200 g, 0.162 mmol) and iron(III) oxide (0.0259 g, 0.162 mmol) were added to a round bottom flask equipped with a stir bar and reflux condenser. To the same flask were added trifluoroacetic acid (6 mL) and D.I. water (1.5 mL) creating a cloudy, dark red suspension upon stirring. Hydroxylamine hydrochloride (0.780 g, 11.2 mmol) was added to the above solution and stirred at 40 °C for 10 minutes. Toluene (3.60 mL, 33.9 mmol) was added and the combined solution was stirred at 100 °C for 5 hours, during which time the solution became clear, dark red. The solution was then cooled to room temperature and neutralized with 30% w/w NaOH. The product was extracted with diethyl ether affording a clear dark red solution (72%).

Formation of Aniline Derivatives: Sodium metavanadate (0.0200 g, 0.162 mmol) and iron(III) oxide (0.0259 g, 0.162 mmol) were added to a round bottom flask equipped with a stir bar and reflux condenser. To the same flask were added trifluoroacetic acid (6 mL) and D.I. water (1.5 mL) creating a cloudy, dark red suspension upon stirring. Hydroxylamine derivative (11.2 mmol) was added to the above solution and stirred at 40 °C for 10 minutes. Benzene derivative (44.9 mmol) was added and the combined solution was stirred at 100 °C for 5 hours. The solution was then cooled to room temperature and neutralized with 30% w/w NaOH. The product was extracted with diethyl ether and characterized by GC or GCMS.

Reaction with methoxyamine hydrochloride. Sodium metavanadate (0.0118 g, 0.097 mmol) and iron(III) oxide (0.0078 g, 0.049 mmol) were added to a round bottom flask equipped with a stir bar and reflux condenser. To the same flask were added trifluoroacetic acid (8 mL) and D.I. water (2 mL) creating a cloudy, dark red suspension upon stirring. Methoxyamine hydrochloride (0.250 g, 3.0 mmol) was added to the above solution and stirred at reflux for 15 minutes. Benzene (0.93 mL, 10.4 mmol) was added and the combined solution was stirred at reflux for 4 hours. The solution was then cooled to room temperature and an aliquot neutralized with 30% w/w NaOH. The product was extracted with diethyl ether and examined by GC. No aniline was detected.

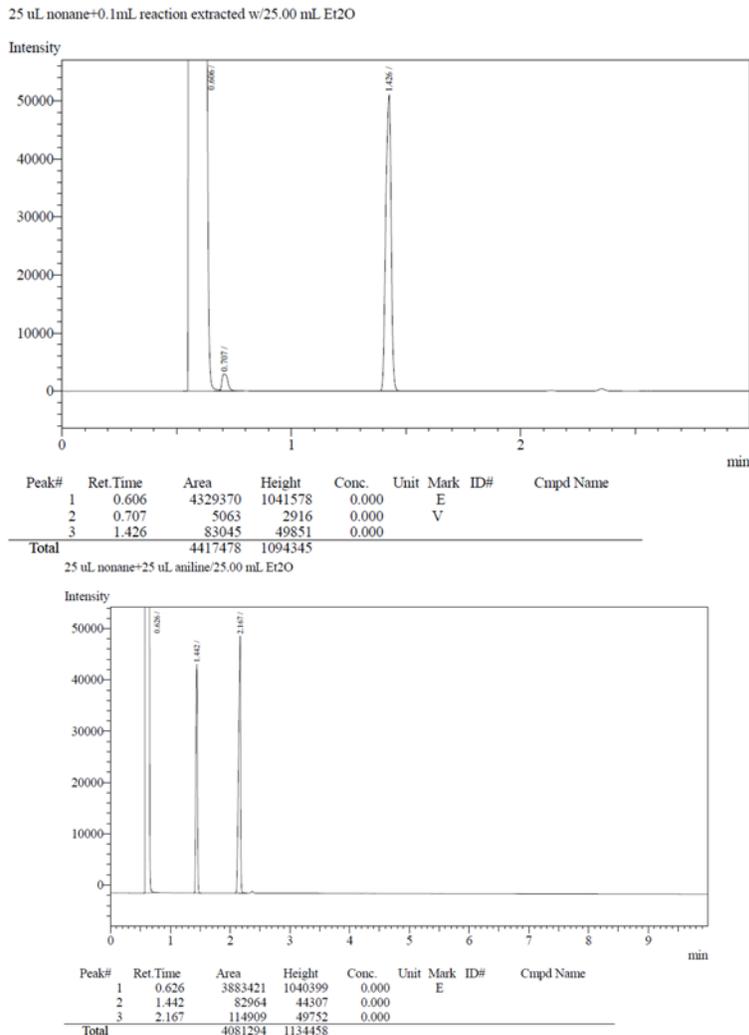


Figure S1. GC trace of reaction with methoxyamine hydrochloride (top) and standard mixture of aniline (2.17 min) with nonane internal standard (1.44 min) (bottom).

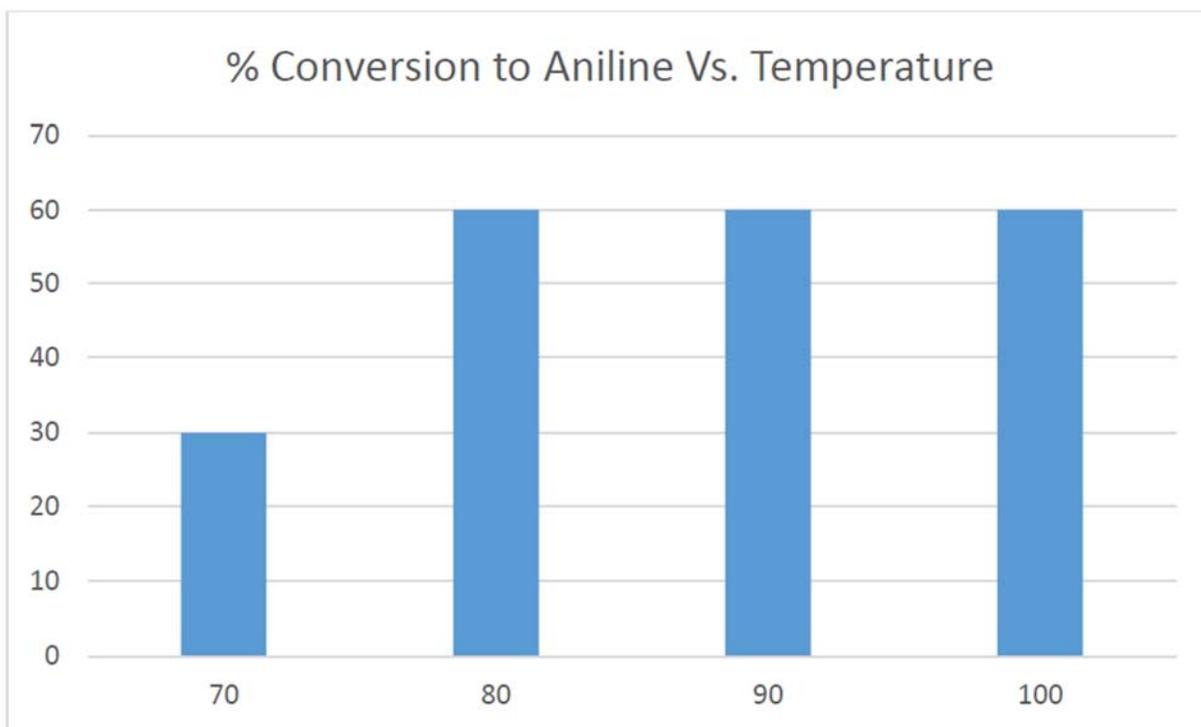


Figure S2 Percent conversion to aniline by temperature. 24 hours, TFA and water. Catalyst is sodium metavanadate.

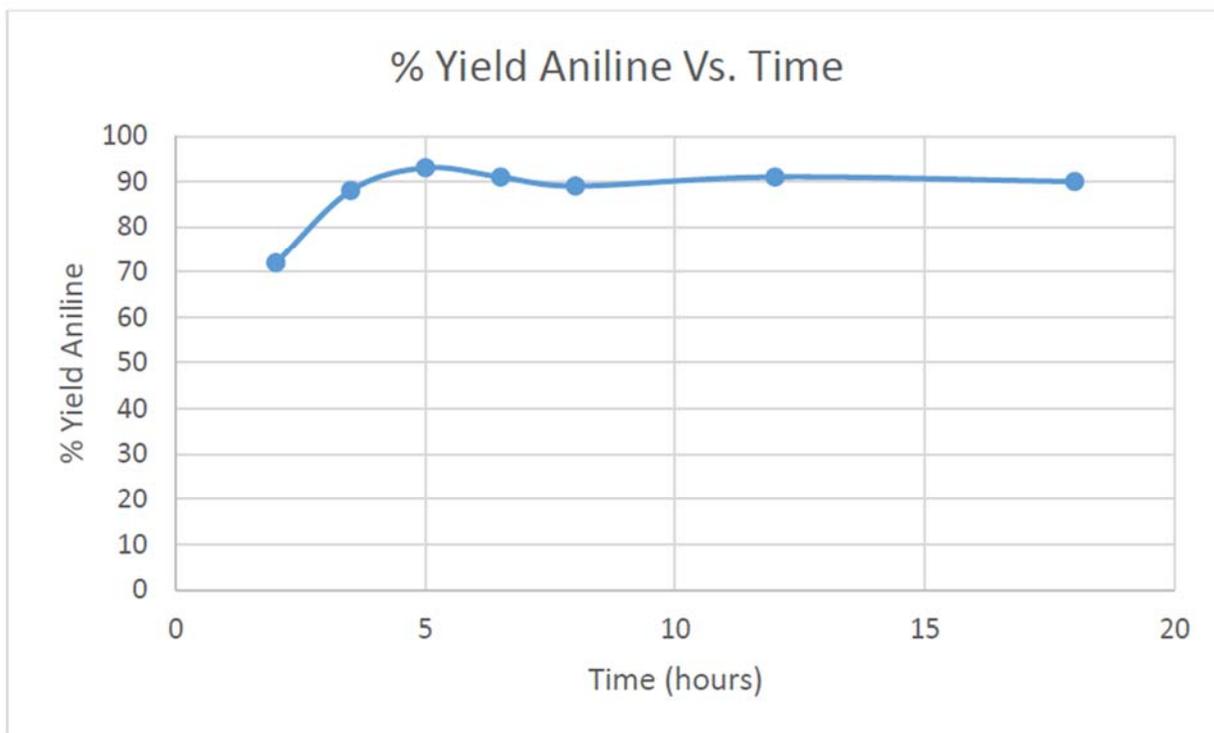


Figure S3. Percent conversion to aniline by time. Co-catalyst system, 100 °C in TFA and water. Catalyst is sodium metavanadate and iron(III) oxide.

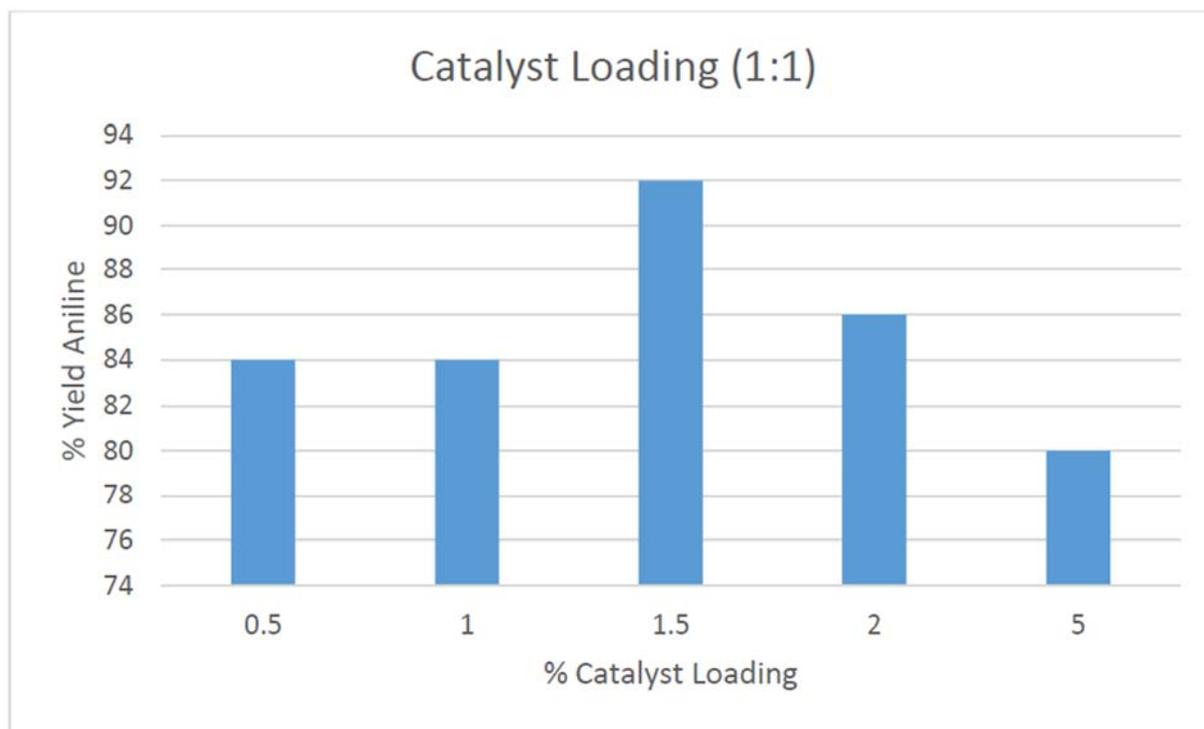


Figure S4. Percent conversion to aniline by catalyst loading. Co-catalyst system, 100 °C in TFA and water, 24 hr. Catalyst is sodium metavanadate and iron(III) oxide.

- 1) Son, S.; Toste, F. D. *Angew. Chem. Int. Ed. Engl.* **2010**, *49*, 3791.
- 2) Hanson, S.; Wu, R.; Silks, L. *Org. Lett.* **2011**, *13*(8), 1908–1911.