COMMUNICATION

ChemComm
www.rsc.org/chemcomm

Catalytic one-pot synthesis of *N*-phenyl alkyl amides from alkene and aniline in the presence of cobalt on charcoal under carbon monoxide†

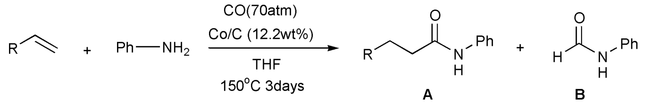
Sang Ick Lee, Seung Uk Son and Young Keun Chung*
School of Chemistry and Center for Molecular Catalysis, Seoul National University, Seoul 151-747, Korea.
E-mail: ykchung@plaza.snu.ac.kr; Fax: +82-2-889-0310; Tel: +82-2-880-6662

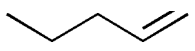
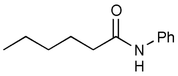
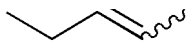
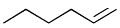
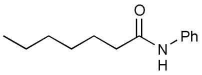
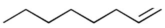
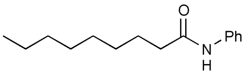
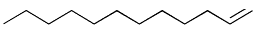
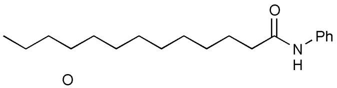
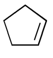
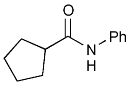
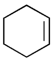
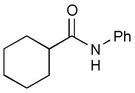
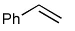
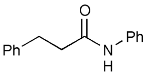
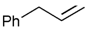
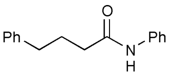
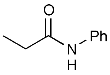
Received (in Cambridge, UK) 15th February 2002, Accepted 17th April 2002
First published as an Advance Article on the web 20th May 2002

***N*-Phenyl alkyl amides were synthesized by the cobalt on charcoal-catalyzed one-pot reaction of alkene and aniline under carbon monoxide; this is the first heterogeneous catalytic formation of *N*-phenyl alkyl amides.**

Amides represent a significant class of compounds owing to their versatility as building blocks and intermediates for chemical industries. A variety of elegant routes have been discovered for the synthesis of amides.[1] Normally, such compounds are prepared by carbonylation of amines with carbon monoxide and through amidation of alkenes or alkynes with carbon monoxide and amines. In particular, Pd-catalysed syntheses of amides from arylic, vinylic, or allenic substrates with amines under carbon monoxide are quite popular.[2] Other transition metal-catalysed reactions such as Pt-catalysed hydration of nitriles[3] and amidation of ethylene with carbon monoxide and ammonia over supported Ru catalysts[4] have also been reported. However, there have been no reports on the cobalt-catalysed amidation of anilines since the cobalt carbonyl-catalysed formation of anilides from aniline, alkene, and carbon monoxide reported a half-century ago.[5] The reported reaction conditions, temperatures (165–223 °C) and pressures (320–450 atm), were too harsh to conduct the reaction in the lab. In a continuation of the use of cobalt on charcoal (Co/C) as a heterogeneous catalyst,[6] we have become interested in amide synthesis from aniline, olefin, and carbon monoxide and tried to moderate the reaction conditions. Herein we report the first heterogeneous catalytic formation of *N*-phenyl alkyl amides from aniline, alkene, and carbon monoxide in the presence of

Table 1 Amidation of various alkenes with aniline[a]



Entry	Substrate	Product		Yield (%)[b]
1			**1A**	90
2			**1A**	70
3			**3A**	84
4			**4A**	80
5			**5A**	50
6			**6A**	74
7			**7A**	35
8			**8A**	2[c]
9			**9A**	30
10			**10A**	54[e] 23[f]

[a] 6 mmol alkene, 3 mmol aniline, and 0.3 g Co/C used. [b] Isolated yields based on aniline. [c] **B** was obtained in 35% yield. [d] 25 atm ethylene at 25 °C used. [e] In water. [f] In THF, **B** was obtained in 53% yield.

---

† Electronic supplementary information (ESI) available: characterization of new compounds. See http://www.rsc.org/suppdata/cc/b2/b201708c/

DOI: 10.1039/b201708c

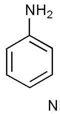
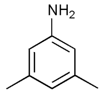
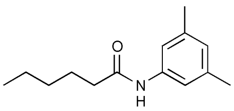
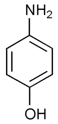
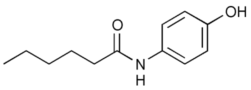
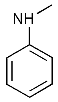
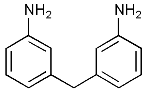
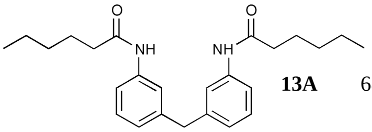
Co/C. Our reaction conditions (150 °C and 70 atm) are much milder than the homogeneous reaction conditions even though they are still harsh and the reaction times are increased.

The amidation was conducted using aniline, alkene, carbon monoxide, and Co/C. The yield of amide is dependent upon the solvent, reaction temperature, pressure of CO, and reaction time. After much experimentation, the optimum conditions were established as follows: in THF, at a temperature of 150 °C, under a CO pressure of 70 atm, and over duration of 3 days. Recovery and reusability of the catalyst system were tested by carrying out consecutive cycles with the same catalyst, carefully separated at the end of each run. However, due to the leaching of the cobalt, the catalyst system can be reused only two times.

We also screened other cobalt carbonyl sources such as $Co_2(CO)_8$† (36% of **1A**), $Co_4(CO)_{12}$ (10% of **1A**), $CoCl(PPh_3)_3$ (3% of **1A**), $CoBr_2$ (trace of **1A**), and colloidal cobalt nanoparticles (46% of **1A**) under the optimized condition. However, best results were obtained in the presence of Co/C. We have screened the amidation reaction of various alkenes under our optimal reaction conditions (Table 1). 1-Pentene and 2-pentene gave the same product, *N*-phenyl pentylamide **1A**, in 70–90% yields. In the case of 2-pentene, a double-bond migration prior to amidation may occur. Co/C is effective for the amidation of higher alkenes such as 1-hexene, 1-octene, and 1-dodecene. Co/C is also effective for cycloalkenes (entries 6 and 7), which were known to be poor substrates in the homogeneous reaction. Aryl alkenes are rather poor substrates (entries 8 and 9). For styrene, formanilide derived from aniline carbonylation was isolated as a major (35% yield) product instead of **8A**. The increase of the carbon chains (entry 9) between phenyl and vinyl groups led to an increase in the yields of the products. Ethylene (entry 10) was a peculiar substrate. When the amidation reaction was conducted in water solution, a 54% yield of the product (based on the aniline) was isolated. However, subjection of ethylene under the same conditions in THF led to isolation of **10A** and formanilide in 23% and 53% yields, respectively.

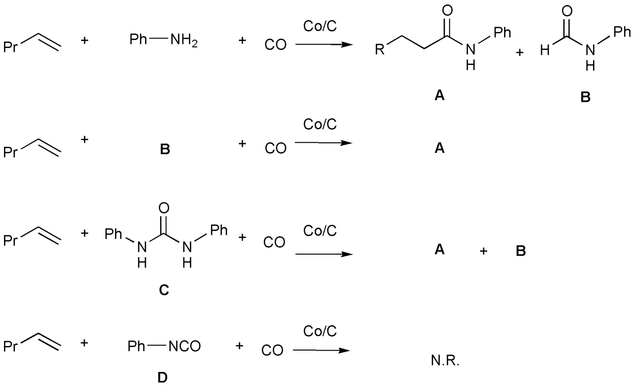
Next we investigated amidation of 1-pentene with aniline derivatives under the same reaction conditions (Table 2). When 3,5-dimethylaniline instead of aniline was used, the expected product was isolated in 53% yield. When 4-aminophenol was used, the amidation product was obtained in a rather poor yield of 23%. At first, we expected a competition between amidation and hydroesterification. However, no hydroesterification product was formed. When *N*-methylaniline was used, no product was observed. Reaction of 3,3’-methylenedianiline yielded a diamidation product in 68% yield. No mono-amidation product was found. The amidation reaction was sensitive to the steric and electronic effect of the substituent(s) on aniline.

Table 2 Amidation of 1-pentene with aniline derivatives[a]

Entry	Substrate	Product		Yield (%)[b]
1			**1A**	90
2			**11A**	53
3			**12A**	23
4		—		NR
5			**13A**	68

[a] 6 mmol alkene, 3 mmol aniline derivatives, and 0.3 g Co/C used. [b] Isolated yields.

It is known[7] that three types (RNHCHO (**B**), RNHC(O)NHR (**C**), RNCO (**D**)) of product can be obtained from the reaction of primary amines with carbon monoxide, depending on the catalyst. In our amidation reaction, the formation of **A** and **B** was observed, but the formation of diphenylurea **C** (R = Ph) or phenyl isocyanate **D** (R = Ph) was not observed (Scheme 1). When **B** was reacted with 1-pentene under our reaction conditions, 17% of **1A** was obtained. Interestingly, treatment of **C** with 1-pentene under our reaction conditions for 3 days gave **1A** in 18% yield, but treatment for 6 days afforded 65% of **1A** and 18% of **1B** (based on the diphenyl urea used), respectively. For **D**, the reactant was recovered. The oxidative addition of aniline followed by insertion of carbon monoxide could be a first step. However, further investigation is needed to firmly establish the mechanism for the present reaction.



Scheme 1

In summary, we have demonstrated that the cobalt on charcoal-catalysed one-pot amidation reaction of alkene and aniline under carbon monoxide produces *N*-phenyl alkyl amides in reasonable to high yields. This is the first heterogeneous catalytic formation of *N*-phenyl alkyl amides. Work is in progress on the use of Co/C in other systems.

This work was supported by grant No. 2000-2-12200-001-1 from the Basic Research Program of the Korea Science and Engineering Foundation (KOSEF) and (1999-1-122-001-5) and the KOSEF through the Center for Molecular Catalysis. SIL thanks the BK21 fellowship.

Notes and references

1 (*a*) M. North, *Contemp. Org. Synth.*, 1994, **1**, 475; (*b*) G. Benz, in *Comprehensive Organic Synthesis*, ed. B. M. Trost and I. Fleming, Pergamon Press, Oxford, 1991, **vol. 6**, p. 381.

2 (*a*) K. Okura, H. Kai and H. Alper, *Tetrahedron: Asymmetry*, 1997, **8**, 2307; (*b*) C. Coperet, T. Sugihara and E.-i. Negishi, *Tetrahedron Lett.*, 1995, **36**, 1771; (*c*) N. D. Trieu, C. J. Elsevier and K. Vrieze, *J. Organomet. Chem.*, 1987, **325**, 23.

3 T. Ghaffar and A. W. Parkins, *J. Mol. Catal. A: Chem.*, 2000, **160**, C249.

4 S.-P. Zhao, S.-I. Sassa, H. Inoue, M. Yzmazakim, H. Watanabe, T. Mori and Y. Morikawa, *J. Mol. Catal. A: Chem.*, 2000, **159**, 103.

5 P. Pino and R. Magri, *Chim. Ind. (Milan)*, 1952, **34**, 511; P. Pino and P. Paleari, *Gazz. Chim. Ital.*, 1951, **81**, 64.

6 S. U. Son, S.-I. Lee and Y. K. Chung, *Angew. Chem., Int. Ed.*, 2000, **39**, 4158.

7 M. B. Smith and J. March, *March’s Advanced Organic Chemistry*, 5th edn., Wiley-Interscience, New York, 2001, p. 820 and references therein.