

Proceeding Paper

Microwave Activation in Fe-Catalyzed Reaction of Binor-S with Nitriles †

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Abstract: An efficient catalytic system consisting of 20 mol. % FeCl₃·6H₂O and 20 mol. % trifluoromethanesulfonic acid for the amidation of binor-S in a solution of toluene with organic nitriles under the action of microwave irradiation at 100 °C for 30 min was developed.

Keywords: amidation; Ritter reaction; binor-S; catalysis; nitriles

1. Introduction

The classical method for the synthesis of *N*-substituted amides is the Ritter reaction of alcohols, haloalkanes, or olefins with nitriles and water catalyzed by H₂SO₄ [1] and HF [2]. The Ritter reaction can also be catalyzed by various Lewis acids based on salts of such transition metals as cobalt [3], copper [4], and iron [5]. Of particular interest is the Ritter reaction with cyclopropane derivatives. Only a few examples of such interaction are known. Thus, iron compounds, and in particular FeCl₃·6H₂O, catalyze the amidation of binor-S with a number of organic nitriles at a temperature of 140–150 °C during the reaction in an autoclave for 6 h. Only a few examples of the reaction of nitriles with cyclopropyl ketones [6], cyclopropanols [7], and arylcyclopropanes [8] are known. Previously, it was found that FeCl₃·6H₂O catalyzed amidation of binor-S [9] and deltacyclene [10], which are cyclopropane-containing polycyclic hydrocarbons, with a number of organic nitriles at a temperature of 140–150 °C during the reaction in an autoclave for 6–12 h. A significant disadvantage of these reactions is the need to use a 16-fold excess of organic nitrile and carry out the reaction at elevated pressure.

In order to develop more efficient catalytic systems for the amidation of cyclopropane-containing polycyclic hydrocarbons, we studied the reaction of binor-S with organic nitriles in the presence of a catalytic system consisting of FeCl₃·6H₂O and trifluoromethanesulfonic acid. We hoped that the use of a binary catalytic system would significantly reduce the reaction temperature and allow it to be carried out at atmospheric pressure.

2. Results and Discussion

We found that the catalytic system, consisting of 20 mol. % FeCl₃·6H₂O and 20 mol. % trifluoromethanesulfonic acid makes it possible to reduce the reaction time of amidation of binor-S in a toluene solution with organic nitriles (propionitrile, cyclopropyl nitrile) to 30 min with a simultaneous decrease in the reaction temperature to 100 °C. The yield of the corresponding amides **1**, **2** was 92–94% (Scheme 1). The use of toluene as a solvent made it possible to reduce the amount of excess organic nitrile used

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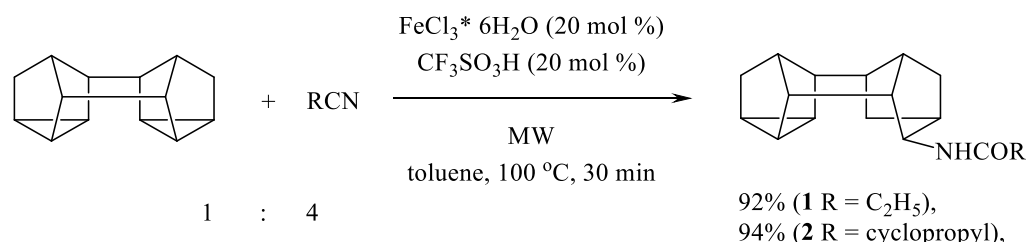
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by four times relative to the original method. However, reducing the amount of organic nitrile used from 4 mmol to 2 mmol leads to a decrease in conversion to 45%. When additional water was used (1 equivalent with respect to binor-S), we observed the formation of the hydroxy derivative of binor-S as a by-product in an amount of up to 20%, which could be a consequence of the interaction of binor-S with water in the reaction conditions.



Scheme 1. Microwave activation in Fe-catalyzed reaction of Binor-S with nitriles.

Thus, the use of a binary system of catalysts made it possible to achieve a fourfold decrease in the amount of organic nitrile used and a decrease in the reaction temperature to 100 °C compared with the previously developed amidation procedure. The latter circumstance made it possible to carry out the binor-S amidation reaction in glass reactors at atmospheric pressure.

3. Conclusions

Thus, we have developed an efficient catalytic system consisting of 20 mol. % FeCl₃·6H₂O and 20 mol. % trifluoromethanesulfonic acid for the amidation of binor-S in a solution of toluene with organic nitriles under the action of microwave irradiation at 100 °C for 30 min.

4. Experimental Part

Propionitrile and cyclopropyl cyanide (Acros) were commercial reagents. ¹H and ¹³C NMR spectra were recorded on a Bruker Avance-II 400 Ascend instrument (400 MHz for ¹H and 100 MHz for ¹³C in CDCl₃). Mass spectra were run on a Shimadzu GCMS-QP2010Plus mass spectrometer (SPB-5 capillary column, 30 m × 0.25 mm, helium as the carrier gas, temperature programming from 40 to 300 °C at 8 °C/min, evaporation temperature of 280 °C, ion source temperature of 200 °C, and ionization energy of 70 eV). The course of the reaction and the purity of the products were monitored by gas liquid chromatography on a Shimadzu GC-9A, GC-2014 instrument [2 m × 3 mm column, SE-30 silicone (5%) on Chromaton N-AW-HMDS as the stationary phase, temperature programming from 50 to 270 °C at 8 °C/min, helium as the carrier gas (47 mL/min)].

Binor-S amidation. General methodology. To a solution of 0.188 g (1 mmol) of binor-S (1) in 1 mL of toluene, 0.054 g (0.2 mmol) of FeCl₃·6H₂O, 0.03 g (0.2 mmol) of trifluoromethanesulfonic acid, nitrile (4 mmol): 0.23 g of propionitrile, 0.27 g cyclopropyl nitrile were added. The reaction was carried out at 100 °C for 0.5 h. After completion, the reaction mixture was washed with water, extracted with ethyl acetate (3 × 1 mL) and the solvent was distilled off under reduced pressure. The residue was recrystallized from ethyl acetate.

N-(hexacyclo [9.2.1.0^{2,7}.0^{3,5}.0^{4,8}.0^{9,13}]tetradec-10-exo-yl)propionamide (1). Yield 0.25 g (92%), white crystals, m.p. 144–145 °C (from ethyl acetate). IR spectrum, (thin layer), ν, cm⁻¹: 3478, 3300, 1635, 1553. Спектр NMR ¹H (CDCl₃), δ, ppm: 5.50 s (1 H, CH), 3.90 d (1 H, CH), 2.24–1.98 m (1 H, CH), 1.98–2.50 m (1 H, CH), 2.50–2.015 m (2 H, CH₂), 1.97–1.96 m (1 H, CH), 1.87–1.85 m (1 H, CH), 1.73–1.70 m (2 H, CH₂), 1.57–1.44 m (2 H, CH₂), 1.37–1.26 m (3 H, CH, CH₂), 1.21–1.19 m (2 H, CH₂), 1.12–1.09 m (4 H, 2CH₂), 0.98–0.91 m (1 H, CH). NMR ¹³C, δ, ppm: 9.95 (C¹⁸), 56.15 (C¹⁰), 46.42 (C⁹), 44.23 (C¹), 41.61 (C²), 40.65 (C⁸), 37.17 (C⁷), 36.08 (C¹³), 34.82 (C¹²), 34.02 (C¹¹), 32.48 (C¹⁴), 31.93 (C⁶), 29.78 (C¹⁷), 15.75 (C⁵), 15.41 (C³), 14.98 (C⁴),

172.79 (CO). MS, m/z (I_{rel}, %): 255 [M]⁺ (20), 184 (24), 228 (49), 57 (69), 200 (100). Found, %: C, 79.40; H 8.97; N 5.50. C₁₇H₂₃NO. Calculated: C, 79.33; H, 9.01; N, 5.44. *M* 255.37.

N-(hexacyclo [9.2.1.0^{2,7}.0^{3,5}.0^{4,8}.0^{9,13}]tetradec-10-*exo*-yl)cyclopropanecarboxamide (2). Yield 0.26 g (94%), white crystals, m.p. 178–180 °C (from ethyl acetate). IR spectrum, (thin layer), ν , cm⁻¹ 3319.95 (NH), 1640.73 (CO). NMR ¹H (CDCl₃), δ , ppm: 0.69–0.7 m (2H, CH₂), 0.95–1.01 m (2H,CH₂), 1.07–1.15 m (2H, 2CH), 1.24–1.26 m (2 H, CH₂), 1.30–1.33 m (2H, CH₂), 1.39–1.41 m (1 H, CH), 1.47–1.50 m (1 H, CH), 1.55–1.62 m (1H, CH), 1.74–1.82 m (2 H, 2CH), 1.89–1.92 m (1 H, CH), 2.01–1.99 m (1H, CH), 2.06–2.08 m (2H, 2CH), 2.10–2.12 m (1H, CH), 3.95–4.13 m (1H.CHNH), 5.73 s (1H, NH). NMR ¹³C, δ , ppm: 6.83 (C¹⁸), 6.97 (C¹⁹), 10.53 (C¹⁷), 14.90 (C⁴), 15.35 (C³), 15.67 35 (C⁵), 31.89 (C⁶), 32.43 (C¹⁴), 33.95 (C¹¹), 34.75 (C¹²), 36.06 (C¹³), 37.13 (C⁷), 40.59 (C⁸), 41.54 (C²), 44.19 (C¹), 37.09 (C¹¹), 46.45 (C⁹), 56.36 (C¹⁰), 172.55 (CO). MS, m/z (I_{rel}, %): 271.18 (2.1) [M]⁺, 270.18 (19.8), 269.18 (100). Found, %: C 80.35; H 8.79; N 5.29. C₁₈H₂₃NO. Calculated, %: C 80.26; H 8.61; N 5.20. *M* 271.39).

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Conflicts of Interest: The authors declare no conflict of interest.

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