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SHORT COMMUNICATIONS

Dedicated to Full Member of the Russian Academy of Sciences G.A. Tolstikov on his 75th annversary

Determining Role of the Catalyst Nature in Concurrent Reactions of 3-Trimethylsilylprop-2-ynal with N- and O-Nucleophiles

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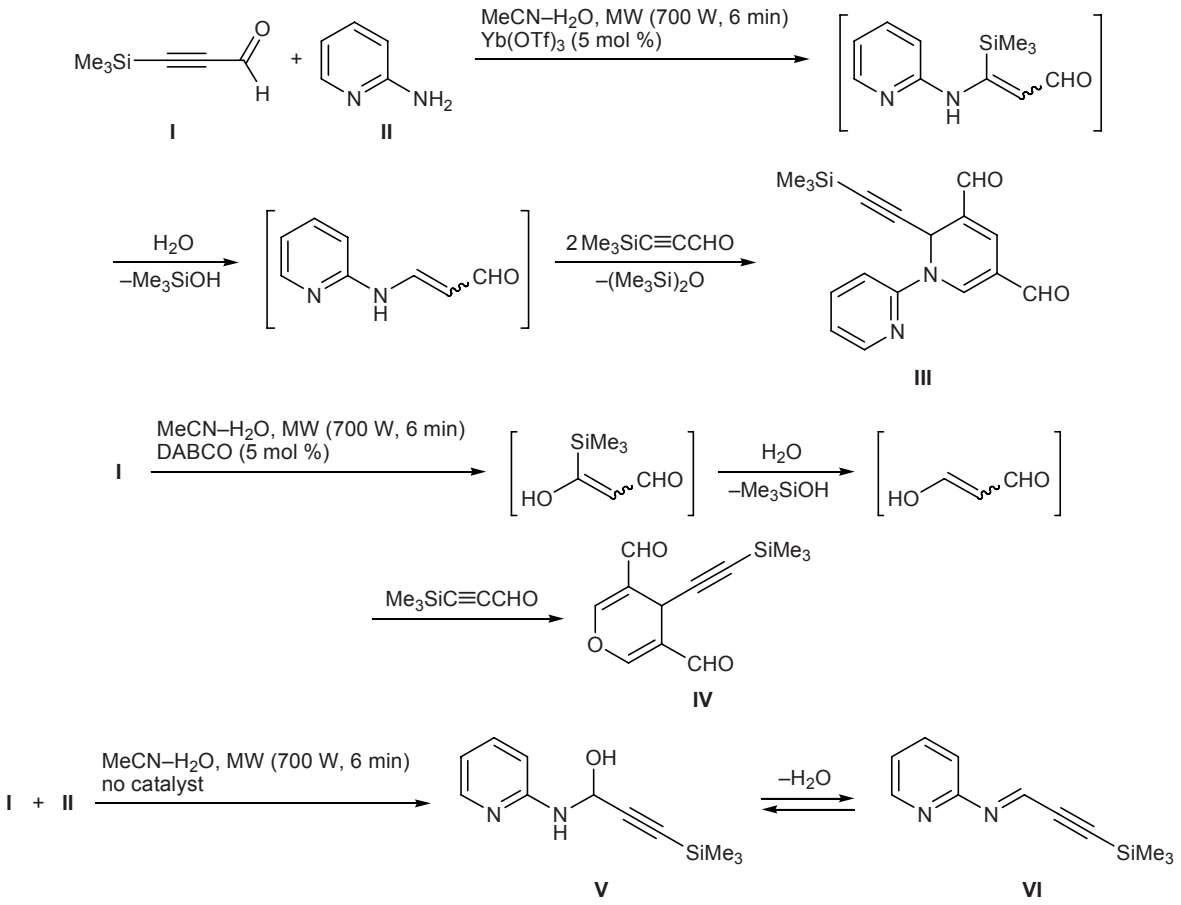
We recently discovered new reactions of heteroelement-containing propynals with some nucleophiles, which resulted in cascade assembly of heterocyclic compounds. For example, 3-trimethylsilylprop-2-ynal (**I**) reacted with pyridin-2-amine (**II**) in the presence of 5 mol % of *p*-toluenesulfonic acid or hydrochloric acid under microwave irradiation (MW, 6 min, 700 W), as well as under usual conditions (25°C, 7 days), to give 75% of *N*-(pyridin-2-yl)-2-(trimethylsilylethynyl)-1,2-dihydropyridine-3,5-dicarbaldehyde [1]. The oxidation of 3-trimethylsilyl(or triethylgermyl)prop-2-yn-1-ol with MnO_2–SiO_2 in the presence of 2-aminopyridine under microwave irradiation led to formation of expected 1,3-azaenynes and imidazo[1,2-*a*]pyridine-3-carbaldehyde [2]. 3-Trimethylsilylprop-2-ynal underwent quantitative trimerization to 4-trimethylsilylethynyl-4*H*-pyran-3,5-dicarbaldehyde, catalyzed by 5 mol % of diazabicyclooctane (DABCO) in acetonitrile [3]. In the absence of a catalyst, propynals having a silicon- or germanium-containing substituent reacted with nitrogen-centered nucleophiles at the aldehyde group with high chemoselectivity [4].

In this paper we demonstrate the determining role of the catalyst nature on the heterocyclization path in the microwave-activated reaction of 3-trimethylsilylprop-2-ynal (**I**) with pyridin-2-amine (**II**) in acetonitrile containing 30 vol % of water. When a mixture of equimolar amounts of aldehyde **I** and aminopyridine **II** in aqueous acetonitrile containing 5 mol % of ytterbium tris(trifluoromethanesulfonate) was irradiated in a microwave oven for 6 min at a power of 700 W, the subsequent chromatographic separation on a column charged with aluminum oxide gave 80% of dihydropyridine **III**. Under MW irradiation, $Yb(OTf)_3$ exhibits a catalytic activity comparable with that of such Brønsted acids as *p*-$MeC_6H_4SO_3H$ and HCl in the cascade assembly of dihydropyridine **III** [1], whereas the reaction performed in the presence of $Yb(OTf)_3$ under usual conditions (25°C, 7 days) gives only the corresponding Schiff base **VI** in 16% yield (according to the ^{1}H NMR data. A high efficiency of ytterbium tris(trifluoromethanesulfonate) in one-pot four-component Hantzsch syntheses of polyhydroquinoline derivatives was reported in [5].

Microwave irradiation of a mixture of compounds **I** and **II** at a ratio of 3:1 (700 W, 6 min) in the presence of a Lewis base (DABCO, 5 mol %) resulted in the formation of 83% of 4-trimethylsilylethynyl-4*H*-pyran-2,6-dicarbaldehyde (**IV**) which was isolated in 58% yield after chromatographic purification on silica gel. The yield of **IV** in the reaction with equimolar amounts of the reactants was 48%. The reaction of aldehyde **I** with amine **II** at a ratio of 1:1 under MW irradiation (700 W, 6 min) in the absence of a catalyst gave only adducts at the aldehyde group, hemiaminal **V** and Schiff base **VI** in 32 and 51% yield, respectively.

The formation of 1,2-dihydropyridine **III** and 4*H*-pyran **IV** involves three trimethylsilylpropynal **I** molecules and one nucleophile molecule. According to the schemes proposed by us for the formation of these heterocycles [3, 4], the key stage in both processes is nucleophilic addition of 2-aminopyridine or water at the triple bond of propynal **I** (Scheme 1). Presumably, DABCO as catalyst facilitates addition of water rather than bulky aminopyridine **II**. It is known that anti-Markovnikov hydration of terminal acetylenes, cata-

Scheme 1.



lyzed by ruthenium complexes, gives the corresponding aldehydes with high selectivity [6–9]. Silicon-containing acetylenic polyfunctional heterocyclic compounds **III** and **IV** may be regarded as promising readily modifiable building blocks for organic synthesis [10].

Thus we have shown that microwave-assisted ytterbium tris(trifluoromethanesulfonate)-catalyzed reaction of 3-trimethylsilylprop-2-ynal with pyridin-2-amine results in cascade assembly of *N*-(pyridin-2-yl)-2-trimethylsilylethynyl-1,2-dihydropyridine-3,5-dicarbaldehyde, while catalysis by a Lewis base (DABCO) promotes trimerization of 3-trimethylsilylprop-2-ynal with formation of 4-trimethylsilylethynyl-4*H*-pyran-2,6-dicarbaldehyde. Under analogous conditions, but in the absence of a catalyst, only adducts at the aldehyde group, 1-(pyridin-2-ylamino)-3-trimethylsilylprop-2-yn-1-ol and *N*-(3-trimethylsilylprop-2-yn-1-ylidene)pyridin-2-amine are formed.

***N*-(Pyridin-2-yl)-2-trimethylsilylethynyl-1,2-dihydropyridine-3,5-dicarbaldehyde (III).** A glass ampule was charged with 0.094 g (1 mmol) of pyridin-2-amine (**II**), 0.03 g (0.05 mmol) of $Yb(OTf)_3$, 0.2 ml of acetonitrile, and 0.08 ml of water (the volume of the reaction mixture should not exceed 1/10 of the ampule capacity). The resulting colorless homogeneous solution was cooled to 0°C, 0.126 g (1 mmol) of aldehyde **I** was added (after addition of **I**, a white solid separated from the solution), and the ampule was sealed and irradiated in a microwave furnace (LG MS-1904H) at a maximal power (700 W) over a period of 6 min in 1-min pulses. The ampule was cooled to room temperature and opened, and the mixture was subjected to chromatography on basic aluminum oxide using acetonitrile as eluent to isolate 83 mg (80%) of compound **III** as a light yellow powder with mp 157–159°C; published data [1]: mp 158–160°C. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 0.15 s (9H, Me_3Si), 6.03 s (1H, NCH), 7.24 d.d (1H, pyridine), 7.47 d (1H, pyridine), 7.57 s (1H, CH=), 7.87 t.d (1H, pyridine), 8.47 d.d (1H, pyridine), 8.74 s (1H, NCH=), 9.50 s (1H, CHO), 9.58 s (1H, CHO). ^{13}C NMR spectrum, δ_C, ppm: –0.35 (Me_3Si), 46.04 (NCH), 91.64 (≡C), 99.88 (SiC≡), 111.23 (pyridine), 115.14 (**C**CHO), 121.18 (pyridine), 125.75 (**C**CHO), 136.05 (**C**H=C), 139.16 (pyridine),

147.53 (N**C**H=C), 148.73 (pyridine), 151.43 (pyridine), 186.44 (CHO), 188.71 (CHO).

4-Trimethylsilylethynyl-4*H*-pyran-2,6-dicarbaldehyde (IV). The reaction was carried out as described above using 0.154 g (1.22 mmol) of aldehyde **I**, 0.038 g (0.41 mmol) of amine **II**, and 0.002 g (5 mol %) of DABCO. The solvent was removed under reduced pressure, and the solid residue was passed through a 0.5×4-cm column charged with KSF montmorillonite using acetonitrile as eluent. The separation process was monitored by TLC on Silufol plates using methanol–chloroform (1:10) as eluent. Removal of the solvent under reduced pressure gave 56 mg (58%) of compound **IV** as light brown powder. ^{1}H NMR spectrum, δ, ppm: 0.07 s (9H, Me_3Si), 4.43 s (1H, CH), 7.34 s (2H, OCH=), 9.51 s (2H, CH=O). ^{13}C NMR spectrum, δ_C, ppm: –0.17 (Me_3Si), 18.99 (**C**HC≡), 86.04 (SiC≡), 103.44 (CH**C**≡), 120.60 (=**C**CH=O), 155.86 (OCH=), 187.69 (CHO).

Reaction of 3-trimethylsilylprop-2-ynal (I) with pyridin-2-amine (II) in the absence of a catalyst. A solution of 0.160 g (1.27 mmol) of aldehyde **I** and 0.119 g (1.27 mmol) of amine **II** in aqueous acetonitrile was irradiated in a microwave furnace under analogous conditions. After removal of the solvent, the solid residue, 0.199 g, was a mixture of 17% of initial aminopyridine **II**, 51% of Schiff base **VI**, and 32% of hemiaminal **V** [according to the ^{1}H NMR data ($CDCl_3$)]. Initial aldehyde **I** was not detected due to its high volatility.

1-(Pyridin-2-ylamino)-3-trimethylsilylprop-2-yn-1-ol (V). ^{1}H NMR spectrum, δ, ppm: 0.13 s (9H, Me_3Si), 5.53 s (1H, NCH), 6.55 d (1H, pyridine), 6.62 m (1H, pyridine), 7.40 m (1H, pyridine), 8.11 d (1H, pyridine).

***N*-(3-Trimethylsilylprop-2-yn-1-ylidene)pyridin-2-amine (VI).** ^{1}H NMR spectrum, δ, ppm: 0.26 s (9H, Me_3Si), 7.19 m (1H, pyridine), 7.32 d (1H, pyridine), 7.72 m (1H, pyridine), 8.42 d (1H, pyridine), 8.52 s (1H, CH=N).

The ^{1}H and ^{13}C NMR spectra were recorded on a Bruker DPX-400 spectrometer using $CDCl_3$ as solvent and hexamethylsiloxane as internal reference.

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