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Heteropolyacids as New Catalysts of the Ritter Reaction

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Abstract—Some nitriles reacted with camphene in the presence of heteropolyacids ($H_3PW_{12}O_{40}$, $H_4SiW_{12}O_{40}$, $H_7PMo_{12}O_{40}$) as catalyst to give *N*-(1,7,7-trimethylbicyclo[2.2.1]hept-2-yl)-substituted amides in fairly high yields.

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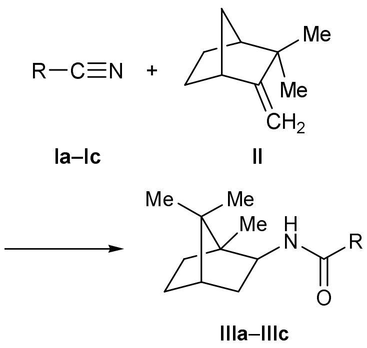
Reaction of nitriles with some alkenes and alcohols in the presence of strong acids is known as the Ritter reaction [1]. It has found wide application for the synthesis of N-substituted amides. Strong mineral acids, such as sulfuric acid, benzenesulfonic acid, methanesulfonic acid, fluorosulfonic acid, anhydrous hydrogen fluoride, and some other acid systems, are used to catalyze this reaction [1, 2].

While searching for new compounds capable of catalyzing the Ritter reaction, we focused on tungsten and molybdenum oxo complexes which are now referred to as heteropolyacids [3]. The structure of these complexes and their specific properties as homogeneous and heterogeneous catalysts were reviewed in detail in [3, 4]. In particular, heteropolyacids are characterized by a high Brønsted acidity and other practically useful properties which underlie their application not only in preparative chemistry but also in a number of large-scale processes [3–6].

Taking into account the above stated, we examined the reactions of nitriles **Ia**–**Ic** with camphene (**II**) in the presence of $H_3PW_{12}O_{40}$ and $H_4SiW_{12}O_{40}$ as most typical heteropolyacid catalysts. In some cases, $H_7PMo_{12}O_{40}$ was also used. The choice of the alkylating agent was dictated by the fact that *N*-(1,7,7-trimethylbicyclo[2.2.1]hept-2-yl)-substituted amides may be important from the practical viewpoint [7]. The reactions were carried out with excess nitrile and addition of water, the camphene-to-catalyst ratio being 2:1. As a result, we isolated the expected *N*-(1,7,7-trimethylbicyclo[2.2.1]hept-2-yl)-substituted amides **IIIa**–**IIIc** in fairly high yields (Scheme 1). When $H_3PW_{12}O_{40}$ was used as catalyst, the yields of compounds **IIIa**–**IIIc** (after recrystallization) were 65, 70, and 64%, respectively. It should be noted that the yield of *N*-(1,7,7-trimethylbicyclo[2.2.1]hept-2-yl)acrylamide (**IIIc**) in an analogous reaction catalyzed by sulfuric acid did not exceed 49% [7].

Scheme 1.



R = Me (**a**), Ph (**b**), CH_2=CH (**c**).

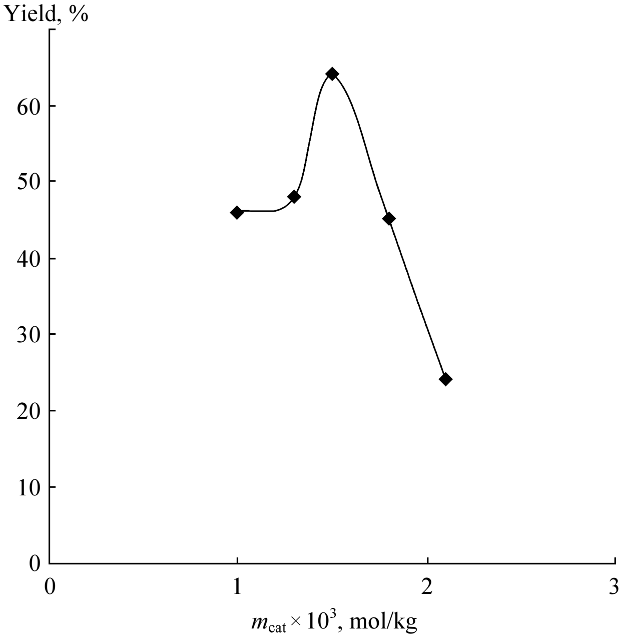
The tungsten oxo complex $H_4SiW_{12}O_{40}$ also turned out to be active catalyst in the examined reaction; however, its catalytic activity did not exceed that of $H_3PW_{12}O_{40}$. Using nitriles **Ib** and **Ic** as examples, we showed that their Ritter reaction with camphene (**II**) may be catalyzed by $H_7PMo_{12}O_{40}$; the yields of compounds **IIIb** and **IIIc** in the presence of that catalyst, as well as in the catalysis by $H_3PW_{12}O_{40}$, were fairly high (no less than 65%).

We studied the dependence of the yield of amide **IIIa** in the reaction catalyzed by $H_3PW_{12}O_{40}$ on the concentration of the latter. The results showed that the dependence is complex. Initially, the yield of **IIIa** increases as the catalyst concentration rises; however, after a certain optimal value, increase in the caalyst concentration leads to sharp reduction in the product yield (see figure).

The reaction of acetonitrile (**Ia**) with camphene (**II**) was also performed in acetic acid as solvent. In this case, the camphene-to-catalyst ratio was 1:1.1, and the amount of the catalyst was $1.7 \cdot 10^{-3}$ mol. After heating for 10 h at 80°C, the yield of **IIIa** was 60%. These data indicate that in some solvents, the nitrile component can be used only as reagent but not as reaction medium.

The structure of compounds **IIIa**–**IIIc** was proved by comparison of their physical constants and spectral parameters (melting points and ^{1}H and ^{13}C NMR and mass spectra) with those of samples synthesized by known methods [7, 8]. We used spectral methods for identification of the products since their melting points were somewhat lower than those given in [7, 8]. The largest difference was observed for compound **IIIa**; however, we failed to isolate the impurity responsible for the lower melting point by fractional recrystallization. Taking into account published data [9], isomers of compound **III** are possible by-products in the reaction under study.

On the basis of the recent data on camphene reactions in the presence of acid catalyst [9], its reactions with nitriles may be represented by Scheme 2. Proton addition to camphene molecule gives carbocation **A** which undergoes Wagner–Meerwein rearrangement to cation **B**, and the latter takes up nitrile molecule to produce final products **IIIa**–**IIIc**. Concurrent formation of isoborneol (**IV**) is also possible; a small amount of compound **IV** was detected in the reaction mixture by GLC. This reaction direction may become the main pathway when the process is performed at a relatively low temperature. For example, when the reaction mixture with acetonitrile (**Ia**) was kept for 20 days at room temperature, the ratio **IV**:**IIIa** was 30:1. After heating of that mixture for 4 h at 65°C, the major product was *N*-(1,7,7-trimethylbicyclo[2.2.1]hept-2-yl)acetamide (**IIIa**) which was isolated in the same yield as indicated above. An analogous result was obtained with isoborneol as alkylating agent (instead of camphene). These data suggest that the transformation of cation **B** into compound **IV** becomes reversible at a moderately high temperature and that the rate-determining stage is the reaction of cation **B** with nitriles.

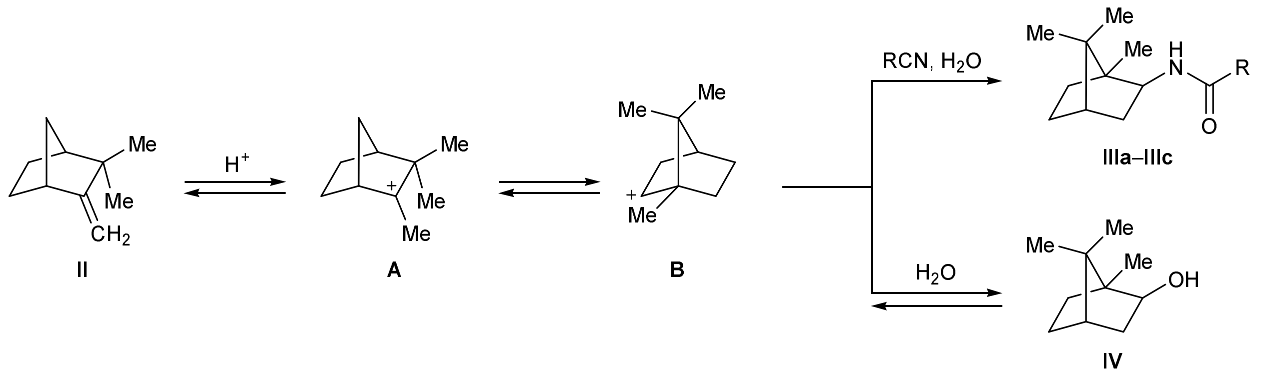


Plot of the yield of *N*-(1,7,7-trimethylbicyclo[2.2.1]hept-2-yl)acetamide (**IIIa**) versus concentration of $H_3PW_{12}O_{40}$. Reaction time 4 h, temperature 80°C.

EXPERIMENTAL

The ^{1}H and ^{13}C NMR spectra were recorded on a Bruker AC-200 spectrometer at 200 and 32 MHz, respectively; the chemical shifts were measured rela-

Scheme 2.



tive to TMS. The mass spectra were obtained on a Finnigan MAT INCOS-50 instrument. The progress of reactions was monitored, and the reaction mixtures were analyzed, by GLC on a Chrom-5 chromatograph equipped with a flame-ionization detector and a stainless steel column (3 m × 5 mm) packed with 15% of PFMS-4 silicone oil on Chromaton N-AW-DMSC (0.20–0.25 mm); injector temperature 230°C; carrier gas nitrogen. Commercial heteropolyacids of pure grade were preliminarily heated for 2 h at 150°C under reduced pressure to remove crystallization water. Nitriles **Ia**–**Ic** were distilled prior to use. Technical-grade camphene was repeatedly recrystallized from ethanol to obtain a sample with mp 44–46°C (published data [10]: mp 48°C); according to the GLC data, it contained 12% of tricyclene.

***N*-(1,7,7-Trimethylbicyclo[2.2.1]hept-2-yl)acetamide (IIIa).** A mixture of 14 ml of acetonitrile (**Ia**), 0.45 g (3.3 mmol) of camphene (**II**), 1 ml (55.6 mmol) of H_2O, and 4.9 g (1.7 mmol) of $H_3PW_{12}O_{40}$ was heated for 8 h at 80°C. When the reaction was complete, the mixture was poured into water and extracted with chloroform. The extract was washed with a 10% aqueous solution of sodium hydroxide and with water until neutral reaction and dried over $CaCl_2$, the solvent was distilled off under reduced pressure, and the residue was recrystallized from hexane. Yield 0.43 g (67%), mp 136–140°C; published data [8]: mp 142–143°C. Repeated recrystallization gave a sample with mp 138–140°C; its mixture with a sample prepared as described in [8] melted at the same temperature. When $H_4SiW_{12}O_{40}$ was used as catalyst, other conditions being equal, the yield of **IIIa** was 0.38 g (60%), mp 136–140°C.

Compounds **IIIb** and **IIIc** were synthesized in a similar way.

***N*-(1,7,7-Trimethylbicyclo[2.2.1]hept-2-yl)benzamide (IIIb)** was obtained by heating a mixture of 8 ml of benzonitrile (**Ib**), 0.30 g (2.2 mmol) of camphene (**II**), 0.5 ml (27.8 mmol) of water, and 4.3 g (1.5 mmol) of $H_3PW_{12}O_{40}$ for 4 h at 65°C. After recrystallization, the yield of **IIIb** was 0.39 g (70%), mp 128–130°C; published data [8]: mp 130°C. When $H_4SiW_{12}O_{40}$ was used as catalyst, the yield of **IIIb** was 0.36 g (65%), mp 128–130°C. The same result was obtained in the reaction catalyzed by $H_7PMo_{12}O_{40}$.

***N*-(1,7,7-Trimethylbicyclo[2.2.1]hept-2-yl)acrylamide (IIIc)** was obtained by heating a mixture of 3 ml of acrylonitrile (**Ic**), 0.095 g (0.7 mmol) of camphene (**II**), 0.2 ml (11.1 mmol) of water, and 0.86 g (0.3 mmol) of $H_3PW_{12}O_{40}$ for 6 h at 80°C. Yield 0.09 g (62%), mp 132–133°C; published data [7]: mp 135–136°C. Analogous results were obtained using $H_4SiW_{12}O_{40}$ and $H_7PMo_{12}O_{40}$ as catalyst.

Reaction of acetonitrile (Ia) with camphene (II) in acetic acid. A mixture of 14 ml of acetic acid, 0.45 g (3.3 mmol) of camphene (**II**), 0.148 g (3.6 mmol) of acetonitrile (**Ia**), 10.5 g (3.6 mmol) of $H_3PW_{12}O_4$, and 1 ml (55.6 mmol) of water was heated for 10 h at 80°C. The mixture was poured into water and extracted with chloroform. The extract was washed with a 10% aqueous solution of sodium hydroxide and with water until neutral reaction and dried over $CaCl_2$, the solvent was distilled off under reduced pressure, and the residue was recrystallized from hexane. Yield of **IIIa** 0.39 g (57%), mp 135–136°C.

REFERENCES

1. March, J., *Advanced Organic Chemistry. Reactions, Mechanisms, and Structure*, New York: Wiley, 1985. Translated under the title *Organicheskaya khimiya*, Moscow: Mir, 1987, vol. 3, p. 416.
2. Kazakov, S.A., Kazantsev, O.A., and Malyshev, A.P., *Zh. Prikl. Khim.*, 2002, vol. 75, p. 2066.
3. Kozhevnikov, I.V., *Usp. Khim.*, 1987, vol. 56, p. 1417.
4. Kozhevnikov, I.V., *Usp. Khim.*, 1993, vol. 62, p. 510.
5. Maksimov, G.M., *Usp. Khim.*, 1995, vol. 64, p. 480.
6. Chernyshkova, F.A., *Neftekhimiya*, 1991, vol. 31, p. 579.
7. Sasaki, T., Eguchi, S., and Oyobe, T., *Bull. Chem. Soc. Jpn.*, 1970, vol. 43, p. 1252.
8. Ritter, J.J. and Minieri, P.P., *J. Am. Chem. Soc.*, 1948, vol. 70, p. 4045.
9. Fomenko, V.V., Korchagina, D.V., Yarovaya, O.I., Gatilov, Yu.V., Salakhutdinov, N.F., Ione, K.G., and Barkhash, V.A., *Russ. J. Org. Chem.*, 1999, vol. 35, p. 1006.
10. Rudakov, G.A. and Kalinovskaya, E.A., *Zh. Org. Khim.*, 1965, vol. 1, p. 1199.