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Journal of Molecular Catalysis A: Chemical 264 (2007) 22–25
JOURNAL OF MOLECULAR CATALYSIS A: CHEMICAL
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Short communication

Potassium dodecatungstocobaltate trihydrate ($K_5CoW_{12}O_{40}\cdot 3H_2O$): A mild and efficient reusable catalyst for the synthesis of β-acetamido ketones under solvent-free conditions

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Received 11 August 2006; received in revised form 30 August 2006; accepted 2 September 2006
Available online 8 September 2006

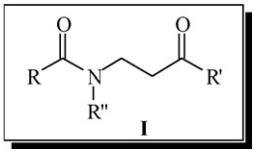
Abstract

A simpler and greener protocol has been developed for the preparation of β-acetamido ketones by a one-pot reaction of aryl aldehydes, enolisable ketones, acetyl chloride and acetonitrile in the presence of potassium dodecatungstocobaltate trihydrate [$K_5CoW_{12}O_{40}\cdot 3H_2O$ (0.01 mol%)] as a heterogeneous catalyst in a solvent-free media at room temperature. The present methodology offers several advantages such as excellent yields, simple procedure, short reaction times (1–2 h) and milder conditions and the catalyst exhibited remarkable reusable activity.

Keywords: Potassium dodecatungstocobaltate trihydrate; β-Acetamido ketones; Solvent-free media; Room temperature; Reusable activity

1. Introduction

β-Acetamido ketones I are fascinating compounds due to their multifunctional nature and are important synthons for a variety of specialty chemicals [1]. They are usually prepared through acylation of β-amino ketones [2], Michael addition to α,β-unsaturated ketones [3] or photoisomerization of phthalimides [4]. The most interesting reaction for the synthesis of these compounds is by multicomponent coupling involving aldehyde, enolisable ketone, acetyl chloride and acetonitrile as first reported by Iqbal and co-workers [5a–d].



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The multicomponent reactions leading to the formation of β-acetylamino ketones can be catalyzed by catalysts such as Montmorillonite K10, $CoCl_2$, cobalt (II) acetate supported on polyaniline, bismuth oxychloride [5e]. β-Acetylamino ketones have also been synthesized using $Cu(OTf)_2$, Zn(II), Bi(III), Sn(II), Sc(III), triflates, BF_3, $CuCl_2$, $BiCl_3$, $LaCl_3$, $LiClO_4$, $InCl_3$ [6], H_2SO_4/SiO_2 [7] and zeolite Hβ [8] (reported as a reusable catalyst). Recently, heteropoly acids (HPAs) have been reported [9] as solid green Bronsted acids for a one-pot synthesis of β-acetylamino ketones by Dakin-West reaction. However, the reported procedures have one or the other disadvantages.

Thus, there is a need for development of an alternative route to construct the β-acetamido ketone derivatives. During the course of our studies directed towards the development of practical, and environmental friendly procedures for some important transformations [10], we developed for the first time the applicability of a novel recyclable heterogeneous catalyst, potassium dodecatungstocobaltate trihydrate [$K_5CoW_{12}O_{40}\cdot 3H_2O$, a heteropoly acid (HPA)] for efficient, convenient and facile preparation of β-acetamido ketones by a one-pot reaction of aryl aldehydes, enolisable ketones, acetyl chloride and acetonitrile in the presence of potassium dodecatungstocobaltate trihydrate [$K_5CoW_{12}O_{40}\cdot 3H_2O$ (0.01 mol%)] as a heterogeneous catalyst in a solvent-free media at room temperature (Scheme 1 and Table 1). To our knowledge, however, the generality and applicability of $K_5CoW_{12}O_{40}\cdot 3H_2O$ to accomplish these reactions have not appeared so far.

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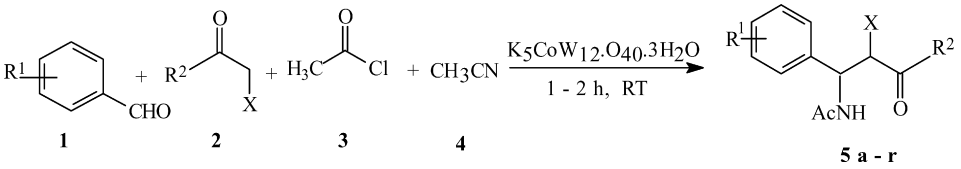
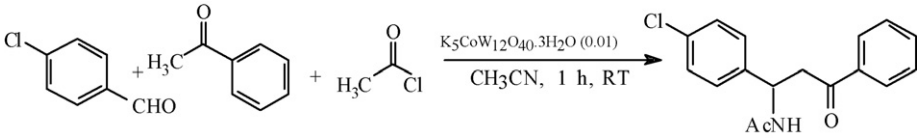
doi:10.1016/j.molcata.2006.09.001



Scheme 1.

Table 1
Optimization in the one-pot reaction of *p*-chloro benzaldehyde, acetophenone, acetyl chloride and acetonitrile



Entry	Catalyst (mol%)	Time (h)	Yield (%)
1	$K_5CoW_{12}O_{40}·3H_2O$ (0.01)	1.0	92
2	$K_5CoW_{12}O_{40}·3H_2O$ (0.05)	2.0	78
3	$K_5CoW_{12}O_{40}·3H_2O$ (0.1)	1.0	96
4	$K_5CoW_{12}O_{40}·3H_2O$ (0.15)	3.0	84

The use of heterogeneous catalysts in different areas of the organic synthesis has now reached significant levels, not only for the possibility to perform environmentally benign synthesis, but also for the good yields, frequently accompanied by heteropoly acids (HPAs) and related compounds is a field of increasing importance [11]. HPAs have several advantages as catalysts which make them economically and environmentally attractive. On one hand, HPAs have a very strong Bronsted acidity approaching the super acid region; on the other, they are efficient oxidants, exhibiting fast reversible multielectron redox transformations under rather mild conditions. Their acid–base and redox properties can be varied over a wide range by changing the chemical composition. Solid HPAs possess a discrete ionic structure, comprising fairly mobile basic structural units – heteropolyanions and counter ion (H^+, H_3O^+, $H_5O_2^+$, etc.) – unlike the network structure of, e.g. zeolites and metal oxides. This unique structure manifests itself to exhibit an extremely high proton mobility and a 'pseudoliquid phase' [12], while heteropolyanions can stabilize cationic organic intermediates [13]. On top of that, HPSD have a very high solubility in polar solvents and fairly high thermal stability in the solid state. These properties render HPAs potentially promising acid, redox, and bifunctional catalysts in homogeneous as well as in heterogeneous systems. HPAs are widely used as model systems for fundamental research, providing unique opportunities for mechanistic studies on the molecular level. At the same time, they have become increasingly important for applied catalysis. In the last two decades, the broad utility of HPA acid and oxidation catalysis has been demonstrated in a wide variety of synthetically useful selective transformation of organic substrates [14]. Several new industrial processes based on heteropolyanion catalysis, such as oxidation of methacrolein, hydration of olefins, polymerization of tetrahydrofuran, etc., have been developed and commercialized [15].

2. Results and discussion

In a typical procedure (Section 5.2), the reaction of enolisable ketones, acetyl chloride, acetonitrile with various aromatic aldehydes in presence of 0.01 mol% of $K_5CoW_{12}O_{40}·3H_2O$ [16] proceeded smoothly at room temperature in 1–2 h to afford excellent yields of β-acetamido ketones (Table 2). The major advantages of $K_5CoW_{12}O_{40}·3H_2O$, shorter reaction times (1–2 h) and the products can be isolated without chromatography, affording β-acetamido ketones in high purity. It is noteworthy that the reported $CoCl_2$ catalyzed reaction, even

Table 2
Synthesis of β-acetylamino ketones at room temperature using ($K_5CoW_{12}O_{40}·3H_2O$ (0.01 mol%))

No	R^1	X	R^2	Time (h)	*syn*/*anti*	Yield (%)[a]
5a	H	H	Ph	1.0	–	86
5b	2-Cl	H	Ph	1.0	–	89
5c	4-Cl	H	Ph	1.0	–	92
5d	2,4-di Cl	H	Ph	1.5	–	91
5e	4-Br	H	Ph	1.0	–	90
5f	2-NO_2	H	Ph	2.0	–	79
5g	3-NO_2	H	Ph	2.0	–	78
5h	4-OCH_3	H	Ph	1.5	–	83
5i	2-OH	H	Ph	2.0	–	76
5j	2,3,4-tri OCH_3	H	Ph	2.0	–	71
5k	4-CN	H	Ph	2.0	–	78
5l	4-CH_3	H	Ph	1.5	–	80
5m	H	CH_3	Ph	2.0	8:92	70
5n	H	$COOCH_3$	CH_3	2.0	28:72	69
5o	4-Br	$COOCH_3$	CH_3	2.0	20:80	77
5p	4-Cl	$COOCH_3$	CH_3	2.0	15:85	73
5q	4-F	$COOCH_3$	CH_3	2.0	7:93	80
5r	4-CH_3	$COOCH_3$	CH_3	2.0	30:70	76

[a] Yields refer to pure products and all products were characterized by comparison of their physical data and ^{1}H NMR, IR spectral data with those of authentic samples.

Table 3
Reuse of the catalyst for synthesis of **5c** (Table 2, entry 3)

Entry	Time (h)	Yield (%)[a]
0	1.0	92
1	1.0	92
2	1.0	91
3	1.5	89
4	2.0	88
5	2.0	87
6	2.5	88
7	3.0	87

[a] Isolated yields.

though carried at room temperature, required longer periods, i.e. 5 days and also required a nonaqueous workup [5b]. The use of Montmorillonite K10 required a high temperature (70 °C) [5a]. Polyaniline supported cobalt (II) acetate required a nitrogen atmosphere [5c]. Zeolite Hβ catalyzed reaction, even though carried out at room temperature required 8–12 h [8], does not require inert atmosphere, reusable, aqueous workup, but our protocol has several advantages, as it does not need an inert atmosphere or a high temperature, involves an aqueous workup and above all requires very short reaction times (1–2 h). The reaction involving acetophenone gave products with only one asymmetric centre (**5a–i**). The reaction involving propiophenone (**5m**) and methyl acetoacetate (**5n**) however, led to diastereomeric mixtures. The ratio of these diastereomers was determined by ^{1}H NMR spectroscopy (Section 5.3). As can be seen from Table 2, the major diastereomer was *anti* in all cases.

3. Reusability of catalyst

In addition, we investigated the reusability and recycling of $K_5CoW_{12}O_{40}\cdot 3H_2O$. At first, we put 0.01 mol% of $K_5CoW_{12}O_{40}\cdot 3H_2O$, *p*-chloro benzaldehyde, acetophenone, acetyl chloride and acetonitrile together, and then the mixture was stirred at room temperature. When the reaction was completed, the catalyst was separated by simple filtration by diluting with acetonitrile and recovered $K_5CoW_{12}O_{40}\cdot 3H_2O$ was reused in subsequent reactions without significant decrease in activity even after seven runs (Table 3).

4. Conclusion

In conclusion, this paper describes a convenient and efficient process for the synthesis of β-acetamido ketones through the four-component coupling of various aromatic aldehydes, enolisable ketone, acetyl chloride and acetonitrile using $K_5CoW_{12}O_{40}\cdot 3H_2O$ as a solid support at room temperature. Present methodology offers very attractive features such as reduced reaction times, higher yields and will have wide scope in organic synthesis. This simple procedure combined with easy of recovery and reuse of the catalyst makes this method economic, benign, and a waste-free chemical process for the synthesis of β-acetamido ketones. We believe that this procedure is convenient, economic, and a user-friendly process for the synthesis of β-acetamido ketones.

5. Experimental

All of the products were characterized by a comparison of their spectral and physical data with those of authentic samples. All yields refer to isolated products. NMR spectra were recorded on a Varian 200 MHz or Bruker 300 MHz. IR spectra were run on a Perkin-Elmer bio-spectrometer. Mass spectra were recorded on VG micromass 7070H or a Finnigan Met 1020B at 70 eV. The purity of the substances and the progress of the reactions were monitored by TLC on silica gel.

5.1. Preparation of the catalyst [16]

The synthesis of potassium dodecatungstocobaltate trihydrate ($K_5CoW_{12}O_{40}\cdot 3H_2O$) starts with the preparation of sodium tungstodicobalt(II)ate from cobaltous acetate (5.0 g, 0.02 mol) and sodium tungstate (39.6 g, 0.12 mol) in acetic acid and water at pH 6.5–7.5. The sodium salt is then converted to the potassium salt by treatment with potassium chloride (26 g). Finally the cobalt(II) complex is oxidized to the cobalt(III) complex by potassium persulfate (20 g) in 80 mL of 2 M H_2SO_4. The crystals of $K_5CoW_{12}O_{40}\cdot 20H_2O$ were dried at 200 °C, after recrystallization with methanol, and potassium dodecatungstocobaltate trihydrate ($K_5CoW_{12}O_{40}\cdot 3H_2O$) were obtained.

5.2. Typical procedure

To a stirred mixture of $K_5CoW_{12}O_{40}\cdot 3H_2O$ (0.01 mol%) in acetonitrile (2.5 mL) were added an aldehyde (106 mg), an enolisable ketone (120 mg) and acetyl chloride (0.4 mL). The reaction mixture was stirred at room temperature for 1–2 h. The mixture was filtered to remove the catalyst and the filtrate was poured into ice-cold water. The precipitated solid was filtered, dried, washed with petroleum ether 60–80 °C to remove any residual starting material and dried. All products were characterized by comparison of their physical constants and spectral data with those for authentic samples [9].

5.3. Representative spectral data

Compound **5a:** mp 101.8–103.4 °C, ^{1}H NMR (200 MHz, $CDCl_3$), δ: 2.04 (s, 3H, Ac), 3.33 (dd, 1H, J = 6.6 and 9.8 Hz), 3.66 (dd, 1H, J = 6.4 and 9.9 Hz), 5.55 (m, 1H), 6.82 (brs, 1H), 7.45 (d, 5H, J = 9.6 Hz), 7.88 (d, 5H, J = 9.0 Hz); IR (KBr, cm^{-1}): 3250, 3030, 1662, 1635, 1574, 1265, 1085. Compound **5c:** mp 141.2–143.0 °C, ^{1}H NMR (300 MHz, $CDCl_3$), δ: 2.01 (s, 3H, Ac), 3.40 (dd, 1H, J = 6.6 and 9.6 Hz), 3.68 (dd, 1H, J = 6.6 and 9.6 Hz), 5.56 (m, 1H), 6.77 (brs, 1H), 7.00 (m, 5H), 7.42 (m, 3H), 7.84 (d, 2H, J = 9.1 Hz); IR (KBr, cm^{-1}): 3263, 3080, 1666, 1565, 1250, 1100. Compound **5g**: mp 110.0–111.6 °C, ^{1}H NMR (200 MHz, $CDCl_3$), δ: 2.04 (s, 3H, Ac), 3.23 (dd, 1H, J = 6.8 and 10.0 Hz), 3.55 (dd, 1H, J = 6.7 and 9.7 Hz), 5.50 (m, 1H), 6.85(brs, 1H), 7.36 (m, 5H), 7.75–8.05 (m, 4H); IR (KBr, cm^{-1}): 3290, 3025, 2255, 1685, 1545, 1452, 760, 685, 555. Compound **5j**: mp 151.3–152.8 °C, ^{1}H NMR (300 MHz, $CDCl_3$), δ: 2.05 (s, 3H, Ac), 3.33 (dd, 1H, J = 6.7 and 10.5 Hz), 3.68 (dd, 1H, J = 6.8 and 10.0 Hz), 3.82 (s, 9H, OCH_3), 5.45

(m, 1H), 6.55 (s, 2H), 6.80 (brs, 1H), 7.45 (t, 2H), 7.65 (t, 1H), 8.05 (d, 2H, $J = 9.5$ Hz); IR (KBr, cm^{-1}): 3270, 3075, 2945, 1695, 1560, 1230, 1125, 750, 680. Compound **5q**: ^{1}H NMR (300 MHz, $CDCl_3$), δ: 2.02 (s, 3H, Ac), 2.15 (s, 3H, CH_3) 3.80 (s, 3H, OCH_3), 4.05 (d, 1H, $J = 6.5$ Hz), 5.75 (dd, 1H, $J = 8.6$ and 5.3 Hz), 6.85 (brs, 1H), 6.88 (d, 2H, $J = 9.4$ Hz), 7.28 (d, 2H, $J = 9.6$ Hz); IR (KBr, cm^{-1}): 3275, 1750, 1725, 1658, 1510.

Acknowledgement

The authors are thankful to Dr. J.S. Yadav, Director and Dr. M. Hari Babu, Deputy Director and Head, Organic Chemistry Division-II, IICT for providing facilities and helpful discussions.

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