Silica-PCL$_5$: An Efficient and Reusable Catalyst for Cyclodehydration of 1, 3-Diketones to Flavones

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ABSTRACT

Silica-PCl$_5$ was employed as efficient solid acid catalyst for conversion of 1, 3-diketones to flavones under solvent-free condition. Reaction is simple, efficient with easy work up and the catalyst is recyclable.

Keywords: 1, 3- Diketones, Silica- PCl$_5$, Dehydrative cyclization, Flavones

INTRODUCTION

The flavones are important class of naturally occurring heterocyclic compounds belonging to the flavonoid group. These exhibit a wide range of biological properties such as antioxidant, anti-infective, anti-inflammatory, anti-cancerous etc[1]. Due to their profound biological activities there is a continued interest in developing new synthetic approaches for their synthesis. Though, a number of methods are available for the preparation of flavones[2] but still, their preparation from β-diketones *via* Baker-Venkataraman[3] is the most accepted method. This method consists of cyclodehydration of β-diketones to flavones which is an acid catalyzed reaction. A number of acid catalyst such as Co^{III}(sulfur)OH[4], FeCl$_3$[5], Br$_2$/CHCl$_3$[6], EtOH/HCl[7], Amberlyst-15[8], Montmorillonite K 10 clay[9], NaOAc/AcOH[10], CuCl$_2$[11] and H$_2$SO$_4$[12] under various reaction conditions have been used to effect this reaction.

The demand of increasingly clean and efficient chemical synthesis is continuously becoming more urgent both from an economic and an environmental view point. In this context, heterogenised reagents are being widely accepted in organic synthesis. [13, 14] Through heterogenisation, easier handling and lower toxicity can be achieved for toxic, explosive, or malodorous reagents, as supported reagents are safer and more convenient than their solution phase equivalents. Another important motive for heterogenisation is the facile isolation of the pure product. Recently we have developeds silica-PCl$_5$ as a solid heterogeneous acid catalyst.[15] We were interested in extending the scope of this reagent in organic synthesis; hence we investigated this reagent for dehydrative cyclization of 1, 3-diketones to flavones. Herein, we wish to report our results. Silica-PCl$_5$ is prepared conveniently from silica and PCl$_5$ which is inexpensive and easily available.

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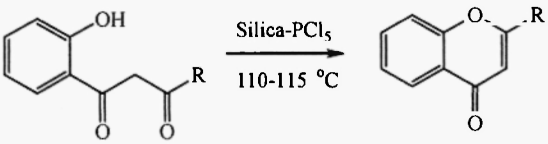
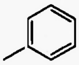
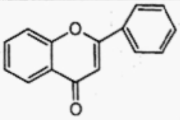
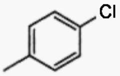
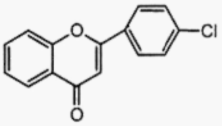
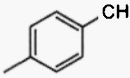
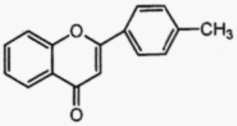
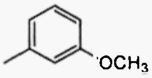
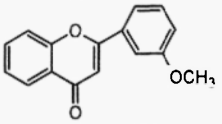
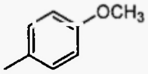
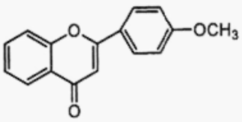
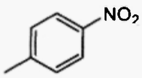
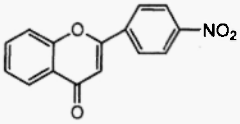
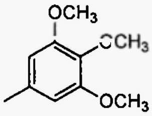
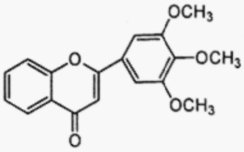
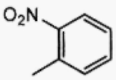
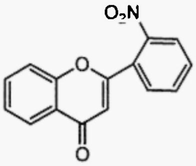
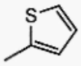
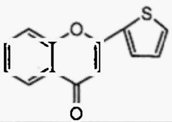
Table 1

Synthesis of flavones from 1, 3-diketones



1-9a **1-9b**

Entry	R	Product [a]	Yield [b] (%)	Time (min)
1			96	75
2			92	70
3			93	75
4			93	90
5			91	75
6			92	80
7			89	150
8			91	80
9			91	120

[a] All products were identified by comparison of their physical and spectral data with those reported in literature.

[b] Isolated yield.

RESULT AND DISCUSSION

To study the feasibility of the reaction 1-(2-Hydroxy-phenyl)-3-phenyl-propane-1, 3-dione **1a** was selected as model substrate. Initially the reaction was carried by heating 1mmol of **1a** with 0.5 g of silica-PCl_5 in 1 ml of water at reflux and the reaction was monitored by TLC (hexane : ethylacetate, 80:20). Though the reaction was found to occur but, the conversion was very slow. Next, we tried the reaction by mixing the reagents in same amount without any solvent at higher temperature (130-150 °C); under these conditions also the reaction progresses slowly. After various experiments we noted that conversion was faster when a very limited amount of water was added to the reaction mixture. Since in this reaction water is released, excess of water retards the reaction. Finally, best results were obtained when a mixture containing 1 mmol of **1a**, 0.5 g of silica-PCl_5 and a small amount of water was heated at 110-115 °C. Within 75-80 min there was a clean conversion of **1a** to corresponding flavone **1b**.

After having optimized the reaction conditions, applicability of this method to various β-diketones with different functional groups was studied and it was found to be of general applicability. No significant difference in reactivity of the substrates containing electron donating or electron withdrawing groups was observed. But, bulky molecules such as 1-(2-Hydroxy-phenyl)-3-(3, 4, 5-trimethoxy-phenyl)-propane-1, 3-dione **7a** took more time for reaction completion. Reusability is one of the additional attractive features of Silica-PCl_5. The cyclisation of **1a** to flavone was studied to investigate the reusability of the catalyst. It was found that catalyst can be recycled for at least three times to yield 2-Phenyl-chromen-4-one **1b** in almost comparable yields, as for the freshly prepared catalyst but, with each recycle; time taken for completion was found to be slightly more than the previous one.

In a typical reaction 1mmol of 1, 3–diketone, 0.5 g Silica-PCl_5 and 50 µl of water was taken together and thoroughly mixed. The contents were then heated at 110-115 °C and the progress of the reaction was monitored by TLC (hexane : ethylacetate, 80:20) . After every 30 min, 50 µl of water was added and heating was continued with occasional mixing till the reaction is complete. Completion of the reaction was monitored by GC-MS analysis. On completion of the reaction, contents were extracted with benzene. Benzene layer was washed with 20% sodium bicarbonate solution. Removal of the solvent under vacuum yielded the pure flavone. Further purification if required, can be achieved by recrystallization from benzene/hexane.

CONCLUSION

In summary, a smooth and clear conversion of 1, 3-diketones to flavones by Silica-PCl_5 has been achieved. Reaction is simple, efficient with easy work up and the catalyst is recyclable. A variety of flavones in good to excellent yields were prepared by the developed method.

Spectral data for selected compounds

2-Phenyl-chromen-4-one 1b

Mp 95-97 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.24 (dd, 1H, J_1=1.9, J_2=8.3), 7.95-7.92 (m, 2H), 7.68 (ddd, 1H, J_1=1.8Hz, J_2=7.2Hz, J_3=8.2Hz), 7.56-7.49 (m, 4H), 7.41 (ddd, 1H, J_1=1.0Hz, J_2=7.2Hz, J_3=8.2Hz), 6.82 (s, 1H).

2-(3, 4, 5-Trimethoxy-phenyl)-chromen-4-one 7b

Mp 173-174 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.25-8.23 (dd, 1H, J_1=1.6Hz, J_2=6.4Hz), 7.71-7.69 (t, 1H, J=1.6Hz), 7.60-7.58 (d, 1H, J=8Hz), 7.45-7.43 (t, 1H, J=8Hz), 7.14 (s, 2H), 6.78 (s, 1H), 3.97 (s, 6H), 3.94 (s, 3H).

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