Sulphamic Acid – An Efficient and Cost-Effective Solid Acid Catalyst for the Pechmann Reaction

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Abstract: Sulphamic acid (H_2NSO_3H, SA) is used as an alternative to conventional acid catalysts in the Pechmann condensation of phenols with β-ketoester leading to the formation of substituted coumarin. The method is simple, cost-effective, solvent-free and gives good yields in a short reaction time.

Key words: sulphamic acid, Pechmann reaction, coumarins

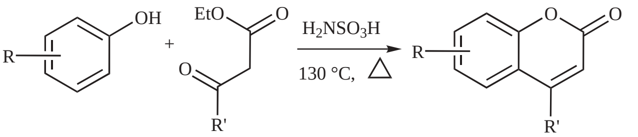
Coumarins and chromones occupy a unique place in the realm of natural and synthetic organic chemistry. Members of this group display a broad range of applications[1,2] as fragrances, pharmaceuticals, additives to foods and cosmetics, agrochemicals, optical brightening agents, dispersal fluorescent and tunable dye lasers[3] and biological activities like antihelminthic, hypnotic, insecticidal and anticoagulant[4] properties. These compounds can also be used for the synthesis of other products such as fluorocoumarins, chromenes, coumarones and 2-acyl resorcinols.[5]

The Pechmann reaction is a most commonly used method for the preparation of coumarins.[6] The reaction involves condensation of very simple starting materials i.e. phenols and β-keto esters in the presence of a variety of acidic condensing agents. Various reagents like H_2SO_4, P_2O_5, $FeCl_3$, $ZnCl_2$, $POCl_3$, $AlCl_3$, PPA, HCl, phosphoric acid, and trifluoroacetic acid are used to effect this condensation.[7] However, in the current context of environmental impact, these methods are not attractive as it requires catalyst in excess, for example, sulfuric acid in 10–12 equivalents,[8] trifluoroacetic acid in 3–4 equivalents[9] and P_2O_5 is required in 5-fold excess.[10] Further, such reactions required long reaction time and in some cases gave lower yields. The present drive therefore is towards the development of more effective, non-stoichiometric, preferably a heterogeneous catalyst. Recently, the solid acid catalysts[11] have been tried for this reaction. The reaction has also been attempted using microwave irradiation[12] and ionic liquids.[13] However, in the case of ionic liquid method, it required the use of HCl for the quenching of the reaction mixture, thus making the process costly and environmentally hazardous.

Sulphamic acid (H_2NSO_3H, SA), which is a common organic acid with mild acidity, involatility and incorrositivity, is insoluble in common organic solvents. It is a very stable white crystalline solid[14a] and it has already been demonstrated that SA is comprised not of the amino sulfonic acid, but rather of $^+H_3NSO_3^-$ zwitterionic units by both X-ray and neutron diffraction techniques.[14b,c] During the last few years, SA has emerged as a promising solid acid catalyst for acid catalyzed reactions, viz. acetalization,[15a] esterification,[15b–15e] acetylation of alcohols and phenols,[15f] nitrile formation,[15g] tetrahydropyranylation of alcohols.[15h] Very recently, SA has been used as a chemoselective catalyst for the transesterification of β-ketoesters[15i] and Beckmann rearrangement.[15j] The unique catalytic feature and intrinsic zwitterionic property of SA is very different from the conventional acidic catalyst, which prompted us to explore the further application of SA as an acidic catalyst in other carbon-carbon and carbon-heteroatom bond forming reactions.

The Pechmann reaction involves initial transesterification of β-ketoester with phenol followed by intramolecular cyclodehydration. In the present work we found that SA alone can catalyze both the steps in the Pechmann reaction.

Herein, we report an efficient SA-catalyzed solvent free Pechmann reaction.



Scheme 1 Pechmann condensation using sulphamic acid (SA) as a catalyst

The reaction of resorcinol with ethyl acetoacetate was selected as a model to test the feasibility of SA used as a catalyst for Pechmann reaction. To optimize the molar stoichiometry of SA required for the reaction, we carried out several experiments at various temperatures and under solvent-less condition. The best result was obtained with 0.5:1:1 molar ratio of SA, resorcinol and ethyl acetoacetate, respectively, at 130 °C. To extend the scope of the reaction and to generalize the procedure, we investigated the reaction of a series of monohydric and polyhydric

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phenols with a variety of β-keto esters to obtain the corresponding coumarins (Table 1).[16] An interesting feature observed was that 3-methoxy phenol (Table 1, entry 2) showed no detectable demethylation under the given conditions. However, reaction by conventional method using $AlCl_3$ in nitrobenzene showed significant demethylation at high temperature.[13a] Naphthols (Table 1, entries 5, 8, 13, and 16) required longer reaction time due to presence of another phenyl group. Phenol, catechol, cresol and *p*-hydroquinone failed to undergo reaction. In general, we observed that the reaction proceeded faster than conventional ones and the yields were comparable.

Table 1 Synthesis of Coumarins from Phenols and β-Keto Esters Catalyzed by Sulphamic Acid[a]

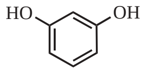
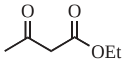
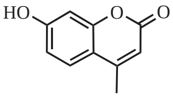
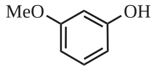
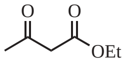
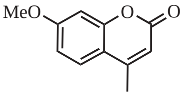
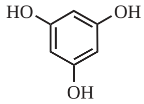
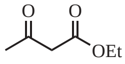
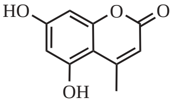
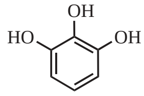
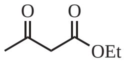
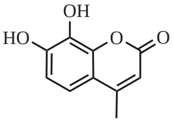
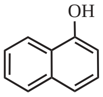
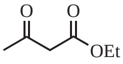
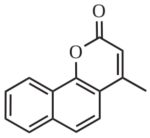
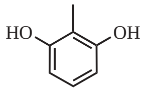
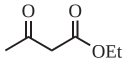
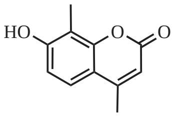
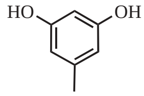
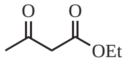
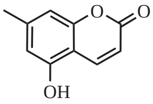
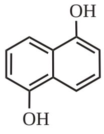
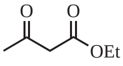
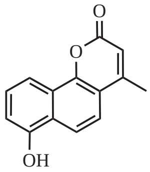
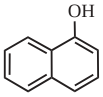
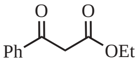
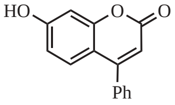
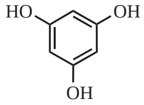
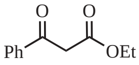
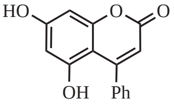
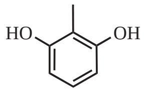
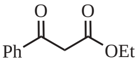
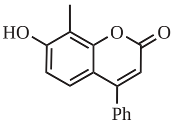
Entry	Substituents (phenols)	β-keto ester	Product	Time (min)	Yield (%)[b]
1				20	94
2				20	88
3				20	96
4				25	82
5				55	68
6				20	85
7				20	88
8				80	62
9				45	80
10				45	82
11				40	82

Table 1 Synthesis of Coumarins from Phenols and β-Keto Esters Catalyzed by Sulphamic Acid[a] (continued)

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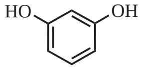
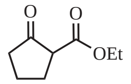
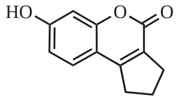
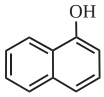
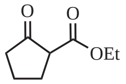
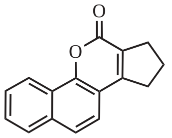
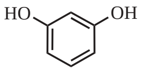
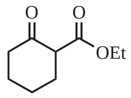
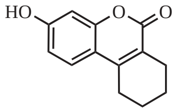
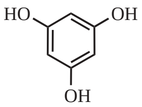
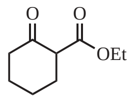
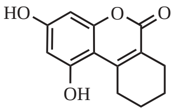
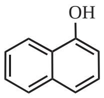
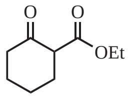
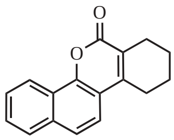
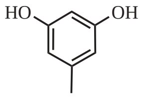
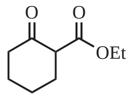
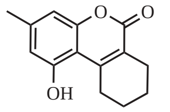
12				50	80
13				60	66
14				25	86
15				25	88
16				80	62
17				55	70

[a] Phenol: 10 mmol; β-ketoester: 10 mmol; SA: 5 mmol; reaction temperature: 130 °C; solventless.

[b] Isolated and unoptimized yields.

In conclusion, we have demonstrated an efficient and simple alternative for the preparation of substituted coumarins via the Pechmann condensation using SA. Prominent among the advantages of this new method are operational simplicity, good yield in short reaction times, solvent-free condition, very inexpensive, easily available catalyst and easy workup procedure employed.

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(16) **Typical Experimental Procedure:** To the weighed quantity of phenol (10 mmol), and β-keto ester (10 mmol), the sulphamic acid (5 mmol) was added and the reaction mixture was stirred at 130 °C in a pre-heated oil-bath. After completion of the reaction at the desired time as indicated in Table 1, the reaction mixture was poured into water and the resultant product was filtered. The products were further purified by column chromatography. The compounds are well known and in agreement with spectral and physical data.