

## Green synthesis of Coumarin derivatives using Fe-K-10 MMT reusable catalyst in Water medium

**Mr. Sagar Narayan Dakhane**

Assistant Professor, MES Abasaheb Garware College, Pune-04 Affiliated to Savitribai pune university Pune  
Maharashtra, India

Email id: [sagarsnd@gmail.com](mailto:sagarsnd@gmail.com)

**Abstract:** A new and efficient condition for the use of Zn-K-10 MMT as a heterogeneous catalyst in the Pechmann condensation reaction in water for the formation of coumarines has been reported. The synthesized coumarins were monitored by TLC and characterized by IR and NMR. The metal catalysts supported on MMT-K10 (Fe-K10, Zn-K10, Ba-K10, Al<sub>2</sub>O<sub>3</sub>-K-10 and ZnO-K-10) were synthesized using a simple wet impregnation method. These catalysts were characterized using various physicochemical techniques like PXRD, FTIR, and BET-surface area. Among the synthesized catalysts, the 10% Fe-K-10 exhibited high conversion up to 100% and high selectivity up to 100% towards coumarine derivatives in 60 minutes. Metal supported Montmorillonite K10-catalyzed reactions between various substituted phenols and ethyl acetoacetate were monitored by LCMS, IR, NMR, and product(s) were isolated, purified, and analyzed (IR, NMR). However, the catalyst was recyclable for ten cycles without loss in catalytic activity.

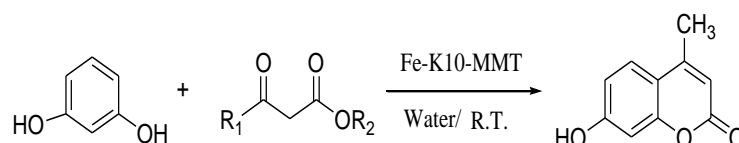
**Keywords:** Pechmann condensation, coumarine, MMT-K-10, impregnation method, recyclable, Montmorillonite K10.

### 1. INTRODUCTION

Coumarines are used as additives in food and cosmetics, optical brightening agents and dispersed fluorescent and laser dyes[1], exhibit useful and diverse biological activity and serve as anticoagulant agents[2]. Synthetic routes to coumarine include Pechmann, Perkin, Knoevenagel and Reformatsky reactions[3]. Pechmann reaction is most widely used method for coumarine synthesis, since it proceeds from simple starting materials like phenols and ethyl acetoacetate. Coumarines can be obtained in high yields upon reaction of ethyl acetoacetate with resorcinol using sulphuric acid and condensing agent [4]. Aluminum chloride and trifluoroacetic acid also act as condensing agent for synthesis of coumarines [5]. Conventional process requires long retain times, corrodes reactors and creates byproducts and salt waste due to acid neutralization. Use of heterogeneous catalysts provides safer operating conditions, ease of product work up, reduced equipment corrosion and minimize waste stream, combined with reusability of catalyst. Among heterogeneous acidic catalysts loaded on Montmorillonite clay K-10 are emerging as attractive solid catalysts for Pechmann condensation of phenols [6, 7]. However, these solid acidic catalysts exhibit limitations of thermal stability and leaching. Nano clays have been one of the significant industrial minerals and with the recent developments of nano clay technology. Montmorillonite,  $\{[M_2(OH)_2(Si_4O_{10})] \cdot xH_2O\}$ , M =

Al and/or Mg is one of the most important nano clay minerals used in various organic reactions [8-10]. Montmorillonite has the capability to exchange various metal cations like Al<sup>3+</sup>, Zn<sup>2+</sup>, Mn<sup>2+</sup>, Fe<sup>3+</sup>, Cu<sup>2+</sup>, Cr<sup>3+</sup>, Ni<sup>2+</sup>, etc. by the cations present in the interlayer of nano clay mineral [11-13]. The catalytic activity of nano clay minerals has been enhanced by manipulating the pore size, intercalating, and replacing interlayer cations and surface area [14]. Several acid-treated montmorillonite clays and high porosity silicas have previously been shown to be effective supports for ZnCl<sub>2</sub>, FeCl<sub>3</sub>, BaCl<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> and ZnO used in many organic transformations. The catalytic activity of ZnCl<sub>2</sub> on these supports, is very much higher than that of the unsupported salt, and these catalysts are of some interest as possible replacements for homogeneous catalysts [15, 16].

The present work reports potential use of FeCl<sub>3</sub> loaded on Montmorillonite clay K-10 denoted by Fe-K-10 MMT as a acid catalyst by studying Pechmann condensation between resorcinol and ethyl acetoacetate to yield 7-hydroxy-4-methyl coumarine in water as a model reaction in scheme 1.



Scheme1: *Synthesis of coumarine catalysed by Fe-K-10 MMT in Water*

Further to study the effect of this acidic heterogeneous catalyst we examined the synthesis of various coumarine derivatives between substituted phenols and ethyl acetoacetate in water.

## 2. MATERIALS AND METHODS

### 2.1 General.

The IR spectrum was taken on a Perkin-Elmer; model 783 spectrophotometer. The NMR spectrum has been recorded by a Bruker AMX-400 (400 MHz) spectrometer. The solvent was DMSO-d<sub>6</sub>. Three chemical shifts are expressed in parts per million (ppm), and tetramethyl silane (TMS) was used as internal reference. Elemental analyses were performed by Perkin Elmer CHN analyzer, 2400 series II.

### 2.2 Preparation of catalyst

A known amount of K-10 (10 g) was stirred with 0.5M ferric chloride solution prepared in water (50 ml) at 80 °C overnight and then cooled to room temperature and the exchanged clay was separated by filtration. The above procedure was repeated once to ensure maximum iron exchange. The residue obtained was filtered and washed twice with 100 ml of distilled water. This iron-exchanged K-10 was dried at 120 °C for 12 h and then calcinated in a muffle furnace at 400 °C. The catalysts with varying concentrations of Fe in K-10 were prepared by taking different ferric chloride stock (0.01–0.5 M) solutions, by following the above procedure. Similarly, Zn/K-10, Ba/K-10, Al<sub>2</sub>O<sub>3</sub>/K-10 and ZnO/K-10 catalysts were prepared by exchanging with the pre-decided stock solutions of the corresponding metal chlorides by following the above procedure. BET surface area of catalysts was determined by a surface area analyzer. The amount of exchanged metals on supports was determined by atomic absorption spectrophotometer. It was characterized by powder XRD and FT-IR.

### 2.3 Typical Procedure for Preparation of Coumarine using Fe-K-10-MMT catalyst

A mixture of resorcinol (110 mg, 1 mmol) and ethyl acetoacetate (130 mg, 1 mmol) and Fe-K-10 MMT catalyst (0.02 g) was heated at 100°C for 60 minutes. After completion of the reaction (monitored by TLC), the residue was dissolved in hot ethanol (2 mL) and filtered to separate the catalyst. The mother liquid was concentrated to 1 mL and cooled in ice bath. The crystalline product was collected by filtration under suction. The pure 7-hydroxy-4-methylcoumarin as colorless prisms was obtained (1.73 g, 98%). This procedure was followed for the preparation of all the substituted coumarins listed in Table 3.

## 3. RESULT AND DISCUSSION

In our studies on developing cheap and environmentally benign methodologies for organic reactions especially solvent-free conditions and using solid acids as a heterogeneous and reusable catalyst we have decided to use FeCl<sub>3</sub> loaded on Montmorillonite clay K-10 as catalyst in Pechmann reaction [17–19], to the best of our knowledge, this catalyst has not yet been used for these types of condensations in water (Scheme 1).

Initially we started with Pechmann condensation of resorcinol and ethyl acetoacetate that had already been used vastly by other chemists in different conditions. In the first glance, we compared ZnCl<sub>2</sub>, BaCl<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, ZnO with FeCl<sub>3</sub> loaded on Montmorillonite clay K-10 for Pechmann condensation. The results are summarized in Table 1.

Table 1: *Pechmann condensation using different metal salts loaded on MMT –K-10 Clay*

Entries	Esters	% yield(isolated)
1	FeCl <sub>3</sub> on MMT K-10	98
2	BaCl <sub>2</sub> on MMT K-10	20
3	Al <sub>2</sub> O <sub>3</sub> on MMT K-10	40
4	ZnO on MMT K-10	30
5	ZnCl <sub>2</sub> on MMT K-10	40

The specific surface area of raw montmorillonite nano clay and amount of Fe was determined by BET methods using a Quantachrome NOVA 1000 surface area analyzer at liquid nitrogen temperature. The surface area of the raw montmorillonite nano clay was found to be 230 m<sup>2</sup> g<sup>-1</sup> and that of Fe/K-10 was 23 m<sup>2</sup> g<sup>-1</sup> for 0.01 molar concentration of FeCl<sub>3</sub> salt. Pyridine adsorption in situ FT-IR spectroscopy was performed for K-10 and Fe incorporated K-10 catalysts. And the spectra recorded after out gassing at 200 °C. Adsorption of pyridine on the parent K-10 clay resulted in absorption bands at 1540 and 1450 cm<sup>-1</sup>, which can be assigned to pyridine molecules interacting with Bronsted and Lewis acid sites, respectively. The surface study of MMT K-10 and metal loaded MMT K-10 was confirmed by XRD and Bronsted and lewis acidic sites were confirmed by IR bands shown in fig.1 Incorporation of Fe led to an increase in Lewis acidity and there is a decrease in the concentration of acid sites with an increase in Fe loading in the range of 0.1–0.6 mmol Fe per gram of K-10. It is seen that Fe/K-10 showed the highest activity with 95% formation of 7-hydroxy-4-methyl coumarin in a solvent-free

condition. The effect of  $\text{Fe}^{3+}$  concentration on the catalytic activity of the Fe/K-10 was studied with  $\text{Fe}^{3+}$  concentrations ranging from 0.01 to 0.50 mmol/g. The formation of coumarine increased linearly up to 0.22 mmol/g of Fe and a further increase has a marginal effect on the

catalytic activity.  $\text{Fe}^{3+}$  is exchanged with interlayer cations as well as the Bronsted acid sites up to a concentration of 0.22 mmol/g. The higher loading results in the incorporation of Zn, Ba and Al species as  $\text{FeCl}_3$  after calcination, which does not contribute to the catalytic activity.

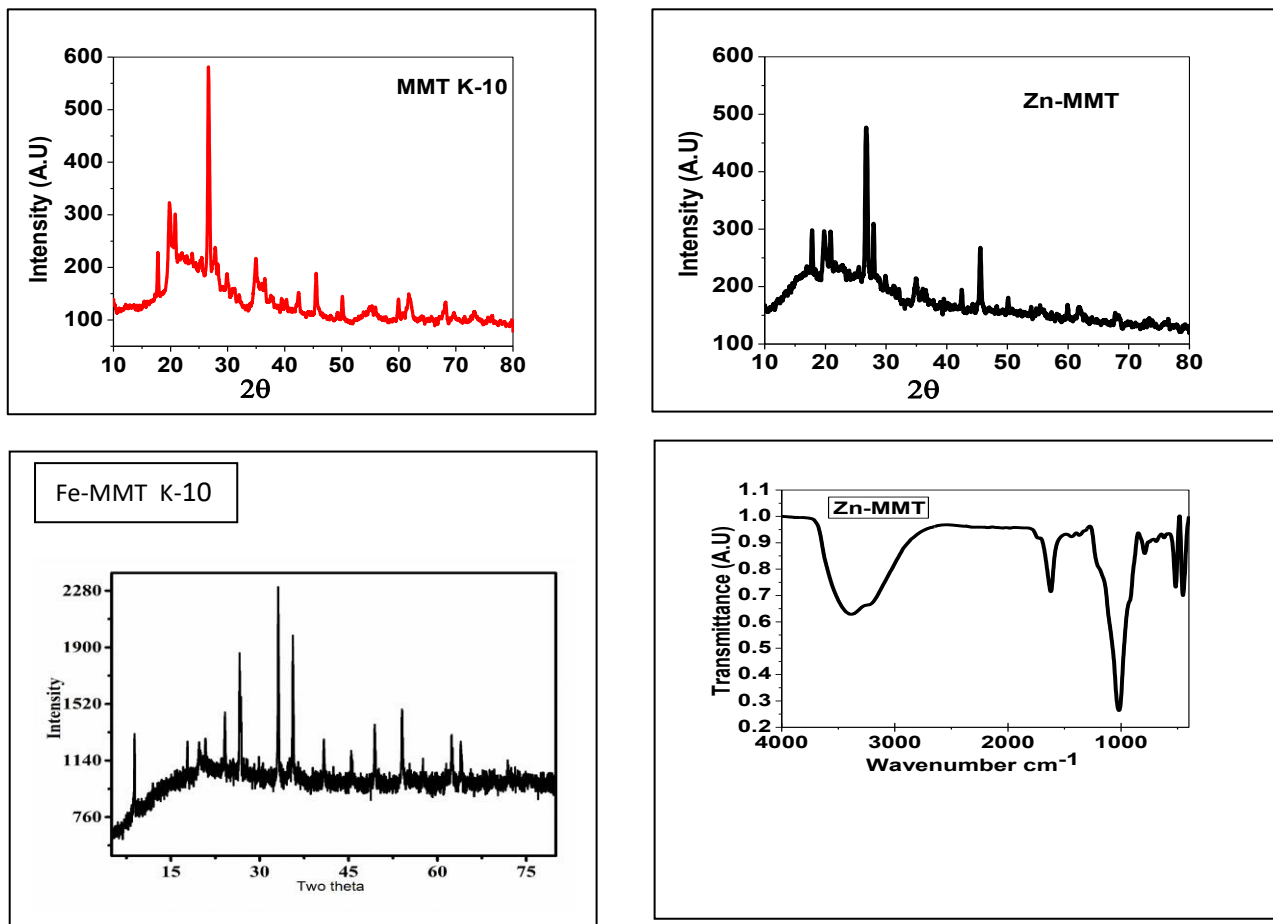


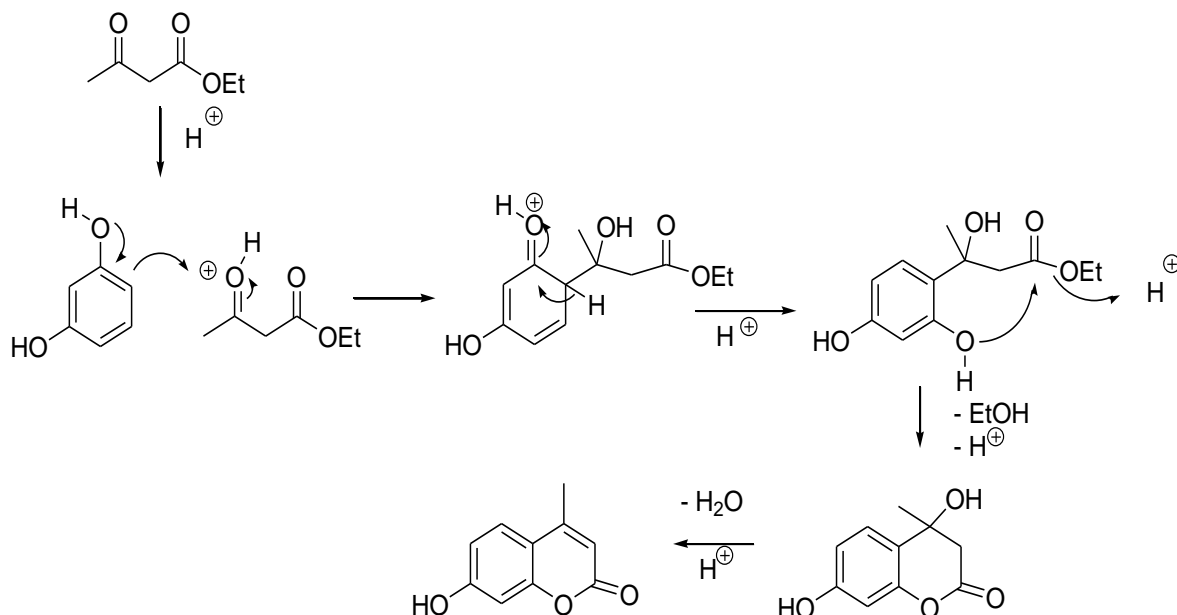
Fig. 1 shows that XRD spectra of MMT-K10 Clay, Metal loaded MMT-K10

Our protocol is efficient for the Pechmann condensation of phenols with electron-donating groups and ethyl acetoacetate even with electron withdrawing groups (Table 3, entries 3-8). All the products were characterized by IR,  $^1\text{H}$  NMR, and  $^{13}\text{C}$  NMR, and were identified by the comparison of the spectral data with those reported in literature. As testing the recyclability of the catalyst, it was separated from the reaction mixture and washed with EtOH and dried at air to give recycled catalyst.

Table 2: The recycling experiment of Fe-K-10 MMT in Pechmann condensation of resorcinol (1 mmol) with ethyl acetoacetate (1 mmol) at RT in water.

Run	1	2	3
Yield(%)	98	97	97

The Pechmann condensation of resorcinol and ethyl acetoacetate was repeated with recycled catalyst and yields were found to remain in the range of 98% for three recycles (Table 2). A proposed mechanism for this reaction is illustrated in Scheme 2.



Scheme 2: A plausible mechanism for the Pechmann condensation of resorcinol and ethyl acetoacetate by acidic site of catalyst

#### 4. CONCLUSION

In conclusion, the efficient use of Fe-K-10 MMT as a heterogeneous catalyst in the Pechmann condensation reaction in water media has been reported. This reaction leads to the formation of coumarin derivatives in excellent yields with good purity. The catalyst has been recycled and reused three times for the reaction without losing its activity. This new condition has several advantages such as good yields, mild conditions, simple workup, and has no environmental hazards. A proposed mechanism has been reported.

Montmorillonite nano clay exchanged with different metal cations ( $\text{Ba}^{2+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Fe}^{3+}$ ) catalyzes the Pechmann condensation of various phenols with ethylacetoacetate. The percentage of yield obtained in this reaction indicated that using  $\text{Fe}^{3+}$ -mont-nano clay has better catalytic activity compared with other metal cation exchanged nano clays. The activity of the  $\text{Fe}^{3+}$  mont nano clay is nearly equal to the catalyst obtained

commercially. The catalyst used has strong Brønsted acid sites to catalyze the reaction. The recyclability of these solid catalysts renders these processes economical.

#### 5. ACKNOWLEDGMENTS

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#### 6. CONFLICTS OF INTEREST

The authors declare that the article was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Table 3: Preparation of different coumarins catalyzed by Zn-K-10 MMT (0.02 g) in water at R,T.

Entry	R1	R2	Phenols	Product	Time (Min)	Yield(%) <sup>*</sup>	M.P. (°C)
1	Me	Et			60	98	182
2	Me	Et			50	98	240
3	Me	Et			50	95	165
4	Me	Et			60	98	172
5	Me	Et			60	95	168
6	Me	Et			75	80	196
7	Me	Et			90	70	183

<sup>\*</sup>isolated yield

## REFERENCES

- [1] S. S. Bahekar and D. B. Shinde, "Samarium(III) catalyzed onepot construction of coumarins," *Tetrahedron Letters*, vol. 45, no. 43, pp. 7999–8001, 2004.
- [2] B. G. Lake, "Coumarin metabolism, toxicity and carcinogenicity: relevance for human risk assessment," *Food and Chemical Toxicology*, vol. 37, pp. 423–453, 1999.
- [3] M. Zahradnik, *The Production and Application of Fluorescent Brightening Agents*, John Wiley & Sons, New York, NY, USA, 1992.

- [4] J. Chen, W. Liu, J. Ma et al., "Synthesis and properties of fluorescence dyes: tetracyclic pyrazolo[3,4-b]pyridine-based coumarin chromophores with intramolecular charge transfer character," *The Journal of Organic Chemistry*, vol. 77, pp. 3475–3482, 2012.
- [5] S. Weigt, N. Huebler, R. Strecker, T. Braunbeck, and T. H. Broschard, "Developmental effects of coumarin and the anticoagulant coumarin derivative warfarin on zebra fish(Danio rerio) embryos," *Reproductive Toxicology*, vol. 33, no. 2, pp. 133–141, 2012.
- [6] F. Hadacek, C. Müller, A. Werner, H. Greger, and P. Proksch, "Analysis, isolation and insecticidal activity of linear furanocoumarins and other coumarin derivatives from Peucedanum (Apiaceae: Apioideae)," *Journal of Chemical Ecology*, vol. 20, pp. 2035–2054, 1994.
- [7] M. Camur, A. A. Esenpinar, A. R. Ozkaya, and M. Bulut, "Synthesis, characterization, spectroscopic and electrochemical properties of phthalocyanines substituted with four 3-ferrocenyl-7-oxycoumarin moieties," *Journal of Organometallic Chemistry*, vol. 696, pp. 1868–1873, 2011.
- [8] D.M. Roundhill, *Chem. Rev.* 91 (1992) 1.
- [9] D.M. Roundhill, *Catal. Today* 92 (1997) 1.
- [10] T.E. Müller, M. Beller, *Chem. Rev.* 98 (1998) 675.
- [11] K. Tanabe, W.F. Hoelderich, *Appl. Catal. A Gen.* 181 (1999) 399.
- [12] R.W. Layer, *Chem. Rev.* 63 (1963) 489.
- [13] J.J. Eisch, R. Sanchez, *J. Org. Chem.* 51 (1986) 1848.
- [14] A. Cobas, E. Guitian, L. Castedo, *J. Org. Chem.* 58 (1993) 3113.
- [15] C. Lorber, R. Choucroun, L. Vendier, *Organometallics* 23 (2004), and references therein.
- [16] A. Heutling, F. Pohlki, S. Doye, *Chem. Eur. J.* 10 (2004) 3059.
- [17] M. Deeba, M.E. Ford, T.A. Johnson, *J. Chem. Soc., Chem. Commun.* 8 (1987) 562.
- [18] M. Deeba, M.E. Ford, *J. Org. Chem.* 53 (1988) 4594.
- [19] V. Kumar, S. Tomar, R. Patel, A. Yousaf, V. S. Parmar, and S. V. Malhotra, "FeCl<sub>3</sub>-catalyzed Pechmann synthesis of coumarins in ionic liquids," *Synthetic Communications*, vol. 38, no. 15, pp. 2646–2654, 2008.