

Ag-CP Mofs As A Green And Sustainable Catalyst For The Synthesis Of Bioactive Heterocyclic Chromene Derivatives

Amol Rangrao Suryawanshi¹, Santosh A. Anantwad², Prof. Sayyad Hussain Sajjansab^{3*}

^{1,2,3*}P. G. Dept of Chemistry, Sir Sayyed College, Roshangate, Aurangabad. (M. S.)India University: Dr Baba Saheb Ambedkar Marathwada University Aurangabad Maharashtra M.S. India 431004

*Corresponding Author: Prof. Sayyad Hussain Sajjansab

P. G. Dept of Chemistry, Sir Sayyed College, Roshangate, Aurangabad. (M. S.)India University: Dr Baba Saheb Ambedkar Marathwada University Aurangabad Maharashtra M.S. India 431004

E-mail: drhussainsyid@yahoo.com

Abstract

Chromenes are well-known bioactive heterocyclic compounds that have played an important role for drug design and are part of many natural products of biological and industrial significance. Herein, novel green and sustainable Silver coordinated co-ordination polymer (Ag-CP) have been synthesized as a heterogeneous catalyst for one pot multicomponent synthesis of series of bioactive heterocyclic chromene derivatives under ambient reaction conditions. The advantageous features of the present energy feasible methodology consist of high yield of the product shorter reaction periods, and recyclability of the catalyst

Keywords: Hydrothermal synthesis, Ag-CP MOFs, Chromene derivatives, heterogeneous catalyst, sustainable.

1. Introduction

Almost all branches of science are following the principles of green chemistry, prominently nanotechnology¹. Still, tremendous growth of industries leads to the release of toxic substances into air, water, and land, thus contaminating the same. Green and sustainable energy sources and alternative variants to existing ones are important to get the cheer shift towards more and more sensible approaches for viable energy availability. Scientists focus to improve the present globe today and for future generations by divulging sufficient ground-breaking solutions and practices to bring about, enthusing the chemical community to reorganize synthetic methodologies across academic and industrial fields. By judging the number of publications in the past decade, today the most fruitful supports for heterogeneous catalysis are Metal organic frameworks (MOFs), which have been investigated in research towards the goal of sustainability. MOFs are porous materials constructed from metal cations or clusters of metal cations which are linked to one another by bridging organic linkers with best ever porosity and an exclusive degree of tunability and as a result it is possible to control their function through molecular design.³ Precisely well-disciplined nanometer-scale having exceptional importance to catalyzing a wide variety of organic reactions in consequence of their capability to put up selectively guest molecules that counterpart the

properties of their cavities due to their assets towards green and sustainable chemistry, this is an alluring viewpoint for heterogeneous catalysis. The recovery of toxic and expensive transition metal species is hugely important and MOFs have proved to be excellent supports and scavengers that can potentially simplify purification procedures in large scale processes. Over the past three decades, in the area of functional materials MOFs have become increasingly dominant. Among the different MOFs, used in catalysis, these have emerged as an important class of multifunctional materials with a rich collection of properties; their ability to function in harsh environments makes them very suitable materials as heterogeneous catalysts. Several studies have demonstrated the use of various MOFs as a heterogeneous catalyst. A prominent example for cyanosilylation of carbonyl compounds using Cd-4,4'-bipyridyl coordination polymer reported by Futija in 1994.⁴ Friedel-Crafts alkylation reactions of electron rich aromatic compounds with nitroolefins catalyzed by urea or squaramide organocatalyst shown by Hupp⁵ and Farha.⁶ Wang L. reported the CH-bond amination catalyzed by MOFs with exceptional activity.⁷ Aldol-Tishchenko reaction reported by Bauer G. MOFs catalyze the reaction. MOFs reported as versatile heterogeneous catalysts for efficient catalytic organic transformations.⁹ epoxidation of assymmetric alkenes using reticular MOFs.¹⁰ Homochiral MOFs for Enantioselective ring-opening of meso-epoxides by aromatic

amines.¹¹ Improvement of catalytic activity by MOFs.¹² MOFs as a catalysts for sequential reactions.¹³ As a catalyst for post synthetic covalent reactions.¹⁴ MOFs as a support for activation methyltrioxorhenium for olefin metathesis.¹⁵ Here, considering the above advantages and scientific study regarding MOFs as a heterogeneous catalytic nanoparticles, we presented the green synthesis of 2-Amino 4-H chromenes derivatives as chromenes received prodigious attention over the last few years, as they display a broad spectrum of biactivities.¹⁶ 2-Amino 4-H chromenes scaffold functions as a generous structural module in naturally and synthetically made drug-like molecules. Recently various green and sustainable methods have been reported for the synthesis of chromene derivatives such as Fe₃O₄-magnetized *N*-pyridin-4-amine-functionalized graphene oxide,¹⁷ Modernite zeolite/MIL-101(Cr) metal-organic,¹⁸ Cu@KCC-1-NH CS₂,¹⁹ Palladium nanoparticles supported with graphene oxide (Pd@GO),²⁰ Dry rind of Aeglemarmelos (bael) fruit ash,²¹ ascorbic acid,²² and many more reports are there for the synthesis of chromene derivatives. Synthesis of chromene derivatives reported by Safaei-Ghomi and workers IL-supported Fe₃O₄,²³ Multi-cationic IL-based catalysts used for the microwave-assisted synthesis of chromene derivatives by Salunkhe and coworkers.²⁴ Synthesis of Inolyl-4H-chromenes derivatives catalyzed by ILs, [TBA][Gly] reported by Rawat and coworkers.²⁵ Considering the beneficial properties of MOFs we intend to synthesize chromene derivatives as green and sustainable routes for biologically active heterocycles, using ethanol as a green solvent which is an eco-friendly method. This method followed green protocols, no hazardous solvents were used and the reactions were run at mild reaction conditions and catalyst recycle feasibility was also explained. In this concern, a novel, highly efficient and stable heterogeneous coordination polymer (CP) as MOFs were prepared by the procedure given in the literature²⁶ and its catalytic activity was examined for the synthesis of chromene derivatives by one pot multicomponent reactions. The use of MOFs as green materials is one of the outstanding properties of this catalyst. Furthermore, high surface area, convenient recovery, and reusability for several times without any significant loss of activity, inexpensive and chemically stable reagents, good reaction times and simple practical methodology; makes this protocol both attractive and economically viable.

2. Experimental

2.1 General

For the synthesis of catalyst, 4, 6-diamino-2-pyrimidinethiol and silver nitrate, were purchased from Sigma-Aldrich. Also, all reagents and solvents in organic synthesis were obtained from Merck and used without further purification. The structures of the known compounds were acknowledged by the comparison of their NMR data/melting points with those reported in the literature. Thin layer chromatography (TLC) was employed for the scrutiny of the reaction progress. Buker Advance DPX FT-NMR spectrometer was applied for running ¹H-NMR (500 MHz). Buchi B-545 apparatus was used for measuring the melting points in open capillary tubes.

3. Examination of catalyst activity for the synthesis of chromene derivatives

To know how the Ag-CP MOFs catalyst works for the synthesis of highly functionalized bioactive chemene derivatives by the reaction of equimolar dione(1) aromatic aldehyde (2) and malanonitrile (3) under reflux condition was expected to formation of desired product in high yield of percentage.

4. Result and Discussion

In order to select most suitable reaction conditions, in the context of green and sustainable chemistry, we began our investigation for optimization of reaction conditions for the synthesis chromene derivatives by performing the reaction of dione (1mmol), aromatic aldehydes (1mmol), and malanonitrile (1mmol) by employing varied amount of solvent, temperature and catalyst the best results were obtained in ethanol in the presence of 10 mg of Ag-CP MOFs as a catalyst under reflux condition for stipulated time period (**Table 1**)

To simplify the whole process and sorts of side reactions, initially the above reactions were conducted with Ag-CP MOFs as a catalyst in ethanol at room temperature and in absence of catalyst there was no formation products was takes place with unreacted starting material (**Table 1** entry 1). Only traces of formation of products takes place when the reaction mixture was heated at 100°C (**Table 2** entry 2) in the absence of either solvent or catalyst there was found to be no any progress of reaction. Under solvent free condition at 100°C if 5 mg of catalyst was loaded the obtained yield of the product was only 50 % (**Table**

1 entry 3). Effectiveness of polar solvent was studied by employing the methanol which is a positive hint for using polar solvent; it gives 60 % yield of product (**Table 1** entry 4). For the purpose of getting higher amount of yield, we checked the reaction in increased amount of catalyst (10 mg) there was formation of 85 % of the product (**Table 1** entry 5). Acetonitrile was used as a solvent in order to check the efficiency of the solvent at room temperature only trace amount of the product was obtained (**Table 1** entry 6). If water was employed as a reaction media very less amount of the product formation was noticed, but when refluxed reaction mixture moderate amount of yield was obtained (**Table 1** entry 7, 8). There was no satisfied amount of yield was obtained if dichloromethane and IPA was used (**Table 1** entry 9, 10, 11). When toluene and ethanol was used the satisfied amount of yield was obtained (**Table 1** entry 12, 13)

Table 1: optimization of the reaction conditions for the synthesis of chromene derivatives^{4a}

Sr. no.	Catalyst (mg)	Solvent	Temp (°C)	Time (h)	Yield (%)
1	-	No solvent	rt	5	0
2	-	No solvent	100	5	trace
3	5	No solvent	100	3	50
4	5	CH ₃ OH	rt	5	60
5	10	CH ₃ OH	rt	4	85
6	10	CH ₃ CN	rt	5	trace
7	10	H ₂ O	rt	6	20
8	10	H ₂ O	Reflux	1	55
9	10	IPA	Reflux	1	trace
10	10	CH ₂ Cl ₂	rt	7	trace
11	10	CH ₂ Cl ₂	Reflux	2	60
12	10	Toluene	rt	2.5	90
13	10	EtOH	reflux	1	97
14	20	EtOH	reflux	1	97

^aReaction conditions: Dimedone (1 mmol), benzaldehyde (1 mmol), malanonitrile (1 mmol), Ag-CP MOFs (10 mol %), and solvent (2 ml) with continuous stirring at reflux temperature.

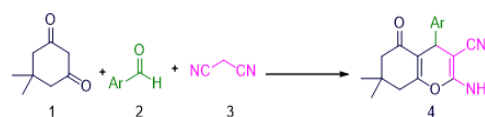
Necessity of polar media for getting best results (**Table 1** entry 13) proved when ethanol was employed to get highest amount of yield, however, an additional enhancement in the catalyst amount up to 20 mg% resulted in no change in conversion percentage. This may be because of the enervation of the catalytic site or knowledge of the highest transformation efficiency of the catalyst.

After discovering the optimized reaction conditions in hand (**Table 1** entry 13), a series of chromene derivatives were synthesized using an equimolar ratio of dimedone (4), aromatic aldehyde (5) and malanonitrile (6) in presence of the Ag-CP MOFs as a catalyst. Many efficient heterogeneous catalysts (Table S1) have been reported for the synthesis of chromene derivatives.

A comparison with these catalytic systems reveals that the present catalyst was more proficient in terms of time, and reaction temperature.

We measured the choice of various aldehydes with a range of substituents on the aromatic ring of aldehyde (**Table 2**). Introduction of electron donating (4-OMe) as well as electron withdrawing substituent's (4-F, 4-Cl, 4-Br, NO₂) at the different positions of aldehydes were well tolerated and products were isolated in 97 % of yield achieved and their structures were confirmed by ¹H-NMR spectra and melting points.

As a part of our efforts towards development of novel, green, sustainable and benign heterogeneous nano catalysts, and their applications as a catalyst in synthesis of bioactive organic complex heterocyclic compounds, we describe here, Ag-CP MOFs as an efficient and recyclable heterogeneous catalyst for one pot three component synthesis of 4H-chromenes (**Scheme 1**)



Scheme 1. Synthesis of 2-amino-7,7-dimethyl-5-oxo-4-phenyl-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile derivatives

Table 2: synthesis of substituted chromene derivatives^a

Entry	Aldehyde	Product	Time(min)	Yield ^b (%)	MP (obsd) (°C)	MP (lit) (°C)
1	C ₆ H ₅ -	4a	30	97	237-238	236-238 ¹⁷
2	4-F-C ₆ H ₄ -	4b	45	92	188-191	189-191 ¹⁸
3	4-OH-C ₆ H ₄ -	4c	25	95	203-204	204-205 ¹⁹
4	4-NO ₂ -C ₆ H ₄ -	4d	60	85	178-179	178-180 ²⁰
5	3-NO ₂ -C ₆ H ₄ -	4e	30	95	210-211	210-211 ²⁰
6	2-Cl-C ₆ H ₄ -	4f	60	90	213-214	212-214 ²¹
7	4-Cl-C ₆ H ₄ -	4g	90	92	213-214	212-214 ²¹
8	4-Me-C ₆ H ₄ -	4h	120	85	208-209	208-210 ²²
9	3-Br-C ₆ H ₄ -	4i	30	90	230-231	229-231 ²³
10	4-OMe-C ₆ H ₄ -	4j	90	80	203-204	203-205 ²⁴
11	3,4-Di-OMe-C ₆ H ₃ -	4f	60	90	230-231	229-231 ²³
12	3-OMe-C ₆ H ₄ -	4g	90	92	197-197	195-197 ²⁴
13	4-Br-C ₆ H ₄ -	4i	90	95	209-210	208-211 ²⁵
14	3-Me-C ₆ H ₄ -	4j	90	93	223-224	224-225 ²⁵
15	3,4-di-Cl-C ₆ H ₃ -	4k	120	90	196-198	196-197 ²⁶

^aReaction conditions: Dimedone (1mmol), benzaldehyde (1 mmol), malanonitrile (1 mmol), Ag-CP (10 mg), and solvent (2 ml) with continuous stirring at reflux temperature.

5. General procedure for the catalytic synthesis of chromene derivatives

A mixture of dimedone (1mmol), aromatic aldehydes (1mmol), and malanonitrile (1mmol) and Ag-CP MOFs (10 mg) was stirred in ethanol under reflux conditions for the required time. The progress of reaction was monitored by TLC. After the completion of reaction, the mixture was cooled down to room temperature. Subsequently, the

catalyst was separated using simple filtration and, then washed by hot ethyl acetate. Finally, the solvent was evaporated and the pure chromene products was obtained through recrystallization in ethanol.

6. Recyclability study of the catalyst

In order to study the scope of the reaction to study the strength of the catalyst, we explored the recyclability study of this catalyst to demonstrate the advantages of the catalyst such as, inexpensiveness, ready availability and heterogeneous character. Only simple filtration method was required to separate the catalyst from the reaction mixture before its reuse without further purification or treatment. Reusability study was carried out by using 4a derivative as a model reaction. The catalyst was found to be active up to six runs with insignificant changes in its activity for its use for next run.

7. Conclusion

In conclusion, Ag-CP MOFs nanoparticles catalyzed the synthesis of densely functionalized 2-Amino 4H-Chromene derivatives using ethanol as green solvent media. This is highly product selective and chromatography free three component reaction protocol, offers several advantages including shorter reaction time with excellent yields, a simple workup procedure, ease of separation and recyclability of the catalyst, as well as a wide variety of aromatic aldehydes. Several green chemistry principles were included (i) one pot multicomponent reaction offering only water as side product (ii) using commercially available substrates with low cost (iii) easy extension of the substrate scope. Finally, representative molecular structure was investigated by means of ¹H NMR spectra which confirm the formation of desired product. Overall this new method meets all the urgent standards set down by green chemistry principles and thereby opens new scopes for further development of sustainable multicomponent reactions.

8. References

Astruc, D.; Lu, F.; Aranzas, J. R., Nanoparticles as recyclable catalysts: The frontier between homogeneous and heterogeneous catalysis. *Angew. Chem. Int. Edit.* **2005**, 44 (48), 7852-7872.

- Anastas, P. T.; Zimmerman, J.B. Design through the Twelve Principles of Green Engineering. *Env. Sci. Tech.* **2003**, 37, 5, 94A-101A.
- Yaghi, O.M., Li, G., Li, H., 1995. Selective binding and removal of guests in a microporous metal-organic framework. *Nature* 378 (6558), 703-706.
- Fujita, M.; Kwon, Y. J.; Washizu, S.; Ogura, K. Preparation, Clathration Ability, and Catalysis of a Two-Dimensional Square Network Material Composed of Cadmium (II) and 4, 4'-Bipyridine. *J. Am. Chem. Soc.* 1994, 116, 1151-1152.
- Roberts, J. M.; Fini, B. M.; Sarjeant, A. A.; Farha, O. K.; Hupp, J. T.; Scheidt, K. A. Urea Metal-Organic Frameworks as Effective and Size-Selective Hydrogen-Bond Catalysts. *J. Am. Chem. Soc.* 2012, 134, 3334-3337.
- McGuirk, C. M.; Katz, M. J.; Stern, C. L.; Sarjeant, A. A.; Hupp, J. T.; Farha, O. K.; Mirkin, C. A. Turning On Catalysis: Incorporation of a Hydrogen-Bond-Donating Squaramide Moiety into a Zr Metal-Organic Framework. *J. Am. Chem. Soc.* 2015, 137, 919-925.
- Wang, L.; Agnew, D. W.; Yu, X.; Figueroa, J. S.; Cohen, S. M. A Metal-Organic Framework with Exceptional Activity for C-H Bond Amination. *Angew. Chem., Int. Ed.* 2018, 57, 511-515.
- Bauer, G.; Ongari, D.; Xi, X.; Tiana, D.; Smit, B.; Ranocchiari, M. Metal-Organic Frameworks Invert Molecular Reactivity: Lewis Acidic Phosphonium Zwitterions Catalyze the Aldol-Tishchenko Reaction. *J. Am. Chem. Soc.* 2017, 139, 18166-18169.
- Chughtai, A. H.; Ahmad, N.; Younus, H. A.; Laypkov, A.; Verpoort, F. Metal-organic frameworks: versatile heterogeneous catalysts for efficient catalytic organic transformations. *Chem. Soc. Rev.* 2015, 44, 6804-6849.
- Song, F.; Wang, C.; Falkowski, J. M.; Ma, L.; Lin, W. Isorecticular Chiral Metal-Organic Frameworks for Asymmetric Alkene Epoxidation: Tuning Catalytic Activity by Controlling Framework Catenation and Varying Open Channel Sizes. *J. Am. Chem. Soc.* 2010, 132, 15390-15398.
- Regati, S.; He, Y.; Thimmaiah, M.; Li, P.; Xiang, S.; Chen, B. Zhao, J. C.-G. Enantioselective ring-opening of meso-epoxides by aromatic amines catalyzed by a homochiral metal-organic framework. *Chem. Commun.* 2013, 49, 9836-9838.
- Burgess, S. A.; Kassie, A.; Baranowski, S. A.; Fritzsche, K. J.; Schmidt-Rohr, K.; Brown, C. M.; Wade, C. R. Improved Catalytic Activity and Stability of a Palladium Pincer Complex by

- Incorporation into a Metal-Organic Framework. *J. Am. Chem. Soc.* 2016, 138, 1780–1783.
- Xia, Q.; Li, Z.; Tan, C.; Liu, Y.; Gong, W.; Cui, Y. Multivariate Metal-Organic Frameworks as Multifunctional Heterogeneous Asymmetric Catalysts for Sequential Reactions. *J. Am. Chem. Soc.* 2017, 139, 8259–8266.
- Fracaroli, A. M.; Siman, P.; Nagib, D. A.; Suzuki, M.; Furukawa, H.; Toste, F. D.; Yaghi, O. M. Seven, Post-synthetic Covalent Reactions in Tandem Leading to Enzyme-like Complexity within Metal-Organic Framework Crystals. *J. Am. Chem. Soc.* 2016, 138, 8352–8355.
- Korzyński, M. D.; Consoli, D. F.; Zhang, S.; Román-Leshkov, Y.; Dincă, M. Activation of Methyltrioxorhenium for Olefin Metathesis in a Zirconium-Based Metal-Organic Framework. *J. Am. Chem. Soc.* 2018, 140, 6956–6960.
- Chitreddy V Subbareddy, and Shanmugam Sumathi., *New J. Chem.*, 2017, **41**, 9388-9396.
- Davood Azarifar, Masoud Khaleghi Abbasabadi., *Research on Chemical Intermediates* volume 45, pages199–222 (2019).
- Mohsen Fallah, Shabnam Sohrabnezhad, Masoumeh Abedini, *Appl Organometal Chem.* 2019; e4801, <https://doi.org/10.1002/aoc.4801>.
- Mahsa Anvari Gharabaghlou, Nasrin Shadjou, Ahmad Poursattar Marjani., Cu@KCC-1-NH-CS₂ as a new and highly efficient nanocatalyst for the synthesis of 2-amino-4H-chromene derivatives, <https://doi.org/10.1002/aoc.5868>
- SuleymanAkocaka,BetülŞen,NabihLolak,AysunŞavk,MuratKoca,SultanKuzu,FatihŞen.,*Nano-Structures & Nano-Objects*, Volume 11, July 2017, Pages 25-31, <https://doi.org/10.1016/j.nanoso.2017.06.002>
- Rupesh C. Patil, Sachinkumar K. Shinde, Uttam P. Patil, Appasaheb T. Birajdar & Suresh S. Patil., A synergetic role of Aegle marmelos fruit ash in the synthesis of biscoumarins and 2-amino-4H-chromenes, *Research on Chemical Intermediates* volume 47, pages1675–1691 (2021).
- Debjit Das, Ascorbic acid: an efficient organocatalyst for environmentally benign synthesis of indole-substituted 4H-chromenes, *Monatshefte für Chemie - Chemical Monthly* volume **152**, pages987–991 (2021).
- Safaei- Ghomi, J.; Eshteghal, F.; Shahbazi- Alavi, H. Novel ionic liquid supported on Fe₃O₄ nanoparticles as an efficient catalyst for the synthesis of new chromenes. *Appl. Organomet. Chem.* 2018, 32(1), DOI 10.1002/aoc.3987.
- Kumbhar, A.; Jadhav, S.; Shejwal, R.; Rashinkar, G.; Salunkhe, R. Application of novelmulti-cationic ionic liquids in microwave assisted 2-amino-4 H-chromene synthesis. *RSC Adv.* 2016, 6 (23), 19612-19619.
- Rajesh, U. C.; Kholiya, R.; Thakur, A.; Rawat, D. S. [TBA] [Gly] ionic liquid promoted multicomponent synthesis of 3-substituted indoles and indolyl-4H-chromenes. *Tetrahedron Lett.* 2015, 56 (14), 1790-1793.
- Noorullah Hussain-Khil, Arash Ghorbani-Choghamarani & Masoud Mohammadi *Scientific Reports* volume 11, Article number: 15657 (2021).
- D. Azarifar, Y. Abbasi, O. Badalkhani, Leucine: green and efficient catalyst for the synthesis of 4H-chromenes *J. Adv. Chem.* 10, 3197 (2014).
- D. Fang, H.B. Zhang, Z.L. Liu, Synthesis of 4H-benzopyrans catalyzed by acyclic acidic ionic liquids in aqueous media.,*J. Heterocycl. Chem.* 47, 63, (2010).
- S. Sarrafi, E. Mehrasbi, A. Vahid, M. Tajbakhsh, Well-Ordered Mesoporous Silica Nanoparticles as a Recoverable Catalyst for One-Pot Multicomponent Synthesis of 4H-Chromene Derivatives *Chin. J. Catal.* 33, 1486 (2012).
- S. Balalaie, M. Bararjanian, M. Sheikh-Ahmadi, S. Hekmat, P. Salehi, Diammonium Hydrogen Phosphate: An Efficient and Versatile Catalyst for the One-Pot Synthesis of Tetrahydrobenzo [b]pyran Derivatives in Aqueous Media *Synth. Commun.* 37, 1097., (2007).
- S. Khaksar, A. Rouhollahpour, S.M. Talesh, A facile and efficient synthesis of 2-amino-3-cyano-4H-chromenes and tetrahydrobenzo[b]pyrans using 2, 2, 2-trifluoroethanol as a metal-free and reusable medium., *J. Fluor. Chem.* 141, 11 (2012).
- D. Azarifar, S.M. Khatami, R. Nejat-Yami, J. Chem. Sci. Nano-titania-supported Preyssler-type heteropolyacid: An efficient and reusable catalyst in ultrasound-promoted synthesis of 4H-chromenes and 4H-pyrano[2,3-c] pyrazoles., 126, 95 (2014).
- M. A. Wanzhen, A. G. Ebadi, M. S. Sabil, R.Javahershenas, G. Jimenez, One-pot synthesis of 2-amino-4H-chromene derivatives by MNPs@Cu as an effective and reusable magnetic nanocatalyst., *RSC Adv.*, 2019, 9, 12801–12812.
- M. Esmailpour, J. Javidi, F. Dehghania, F. N. Dodeji, *RSC Adv.*, A green one-pot three-component synthesis of tetrahydrobenzo[b]pyran and 3,4-dihydropyrano[c]chromene derivatives using a Fe₃O₄@SiO₂-imid-PMAⁿ magnetic nano catalyst under ultrasonic irradiation or reflux conditions., 2015, **5**, 26625.
- R. Y. Guo, Z. M. An, L. P. Mo, R. Z. Wang, H. X. Liu, S. X. Wang, Z. H. Zhang, Meglumine: A Novel and Efficient Catalyst for One-Pot, Three-Component Combinatorial Synthesis of

- Functionalized 2-Amino-4*H*-pyrans., *ACS Comb. Sci.* 15, 557 (2013).
- T. A. J. Siddiqui, a Shoyebmohamad F. Shaikh, Balaji B. Totawar, Madhuri Dumpala, Mohd Ubaidullah, Badr M. Thamer, Rajaram S. Mane and Abdullah M. Al-Enizi., *Dalton Trans.*, 2021, 50, 2032.
- S. Gao, C.H. Tsai, C. Tseng, C.-F. Yao, *Tetrahedron.*, Fluoride ion catalyzed multicomponent reactions for efficient synthesis of 4*H*-chromene and *N*-arylquinoline derivatives in aqueous media., 64, 9143 (2008)
- P. Sharma, M. Gupta, R. Kant, V.K. Gupta, One-pot synthesis of various 2-amino-4*H*-chromene derivatives using a highly active supported ionic liquid catalyst., *RSC Adv.* 6, 32052, (2016)
- S. Zavar, *Arabian J. Chem.*, A novel three component synthesis of 2-amino-4*H*-chromenes derivatives using nano ZnO catalyst., 2017, 10, S67.
- G. Brahmachari, B. Banerjee, Facile and One-Pot Access to Diverse and Densely Functionalized 2-Amino-3-cyano-4*H*-pyrans and Pyran-Annulated Heterocyclic Scaffolds via an Eco-Friendly Multicomponent Reaction at Room Temperature Using Urea as a Novel Organo-Catalyst., *ACS Sustainable Chem. Eng.*, 2014, 2, 411.
- M. R. N. Jamal, S. Mashkouri, A. Sharifi, An efficient, multicomponent approach for solvent-free synthesis of 2-amino-4*H*-chromene scaffold., *Mol. Divers.*, 2010, 14, 473-477.
- C. W. Lü, J. J. Wang, F. Li, S. J. Yu, Efficient synthesis of 2-amino-3-cyano-4*H*-pyran derivatives via a non-catalytic one-pot three-component reaction., *Res. Chem. Intermed.* 2018, 44, 1035.
- G. Sabitha, K. Arundhati, K. Sudhakar, B. S. Sastri, J. S. Yadav, Efficient one-pot synthesis of 4*H*-benzo[*b*]pyrans via a three-component cyclocondensation of aryl aldehydes, malononitrile, and dimedone has been reported using CeCl₃·7H₂O as catalyst., *Synth. Commun.*, 2009, 39, 433-442.
- I. A. Azath, P. Puthiaraj, K. Pitchumani, One-Pot Multicomponent Solvent-Free Synthesis of 2-Amino-4*H*-benzo[*b*]pyrans Catalyzed by Per-6-amino-β-cyclodextrin., *ACS Sustainable Chem. Eng.*, 2013, 1, 174-179.
- S. Abdolmohammadi, S. Balalaie, Novel and efficient catalysts for the one-pot synthesis of 3,4-dihydropyrano[*c*]chromene derivatives in aqueous media., *Tetrahedron Lett.*, 2007, 48, 3299.
- H. Mehrabi, M. K. Mireki, Synthesis and characterization of in-chain silyl-hydride functional SBR and self-crosslinking elastomer, *Chin. Chem. Lett.*, 2011, 22, 1419.
- E. Sheikhsosseini, D. Ghazanfari, V. Nezamabadi, A new method for synthesis of tetrahydrobenzo[*b*]pyrans and dihydropyrano[*c*]chromenes using *p*-dodecylbenzenesulfonic acid as catalyst in water., *Iran. J. Catal.*, 2013, 3, 197-201.
- R. S. Bhosale, C. V. Magar, K. S. Solanke, S. B. Mane, S. S. Choudhary, R. P. Pawar, Molecular Iodine: An Efficient Catalyst for the Synthesis of Tetrahydrobenzo[*b*]pyrans., *Synth. Commun.*, 2007, 37, 4353.

Ag-CP MOFs as a Green and Sustainable Catalyst for the Synthesis of Bioactive Heterocyclic Chromene Derivatives

Table of contents

Preparation of Ag-CP MOFs	S2
Table S1. Assessment of reported catalysts catalytic activity with Ag-CP NRs for the synthesis of chromenes	S2
Mechanism of reaction for the synthesis of chromene derivatives.	S3
¹ H NMR spectra of synthesized chromene derivatives	S4
Spectral data of ¹ H NMR synthesized chromene derivatives	

Preparation of Ag-CP MOFs

To a 1mmol solution of 4, 6-diamino-2-pyrimidinethiol in 2 ml of water, added to a solution of 2mmol AgNO₃ in 12ml DMF. The resulting mixture was stirred at 80 °C under darkness for 20 minutes. Afterwards, the mixture was kept in an autoclave at 160 °C for 24 h (**Scheme 1**). In the next step, the obtained product in powder form from the autoclave was cooled down and washed with ethyl acetate. Subsequently, the obtained Ag-CP MOFs black powder was sonicated for 20 min, dried at room temperature and, finally, stored in dark brown bottle.

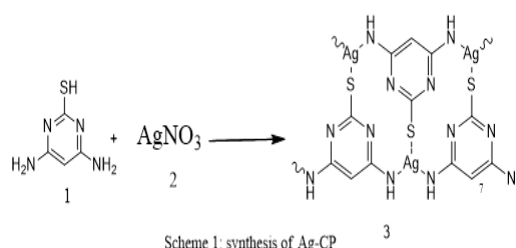


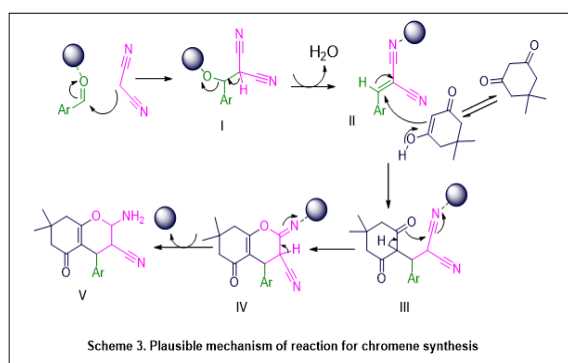
Table S1. Assessment of reported catalysts catalytic activity with Ag-CP NRs for the synthesis of chromenes.

Entry	Catalyst	Catalyst loading	Solvent	Temp (°C)	Time (Min)	Yield (%)	ref
1	No catalyst	-	EtOH:H ₂ O	Reflux	--	--	--
2	ZnO NPs	10 mol%	EtOH	Reflux	20	85	39
3	Urea	10 mol%	EtOH:H ₂ O	Reflux	480	90	40
4	Na ₂ CO ₃	10 mol%	EtOH:H ₂ O	120	100	94	41
5	Aq PEG-400	1ml	EtOH:H ₂ O	Reflux	180	84	42
6	Cerium (III)chloride	10 mol%	EtOH:H ₂ O	Reflux	80	83	43
7	Piperidine		H ₂ O	Reflux	380	80	44
8	S-Proline	10 mol%	EtOH:H ₂ O	Reflux	180	90	45
9	CuO NPs	15 mol%	H ₂ O	100	420	92	46
10	DBSA		H ₂ O		280	90	47
11	I ₂	10 mol%	DMSO	120	250	94	48
12	This catalyst	10 mg	EtOH	70	60	97	This work

^aReaction conditions: Dimedone (1 mmol), benzaldehyde (1 mmol), malanonitrile (1 mmol), different catalysts with variable amounts, solvent (2 ml) with continuous stirring at reflux temperature.

Mechanism of reaction for the synthesis of chromene derivatives.

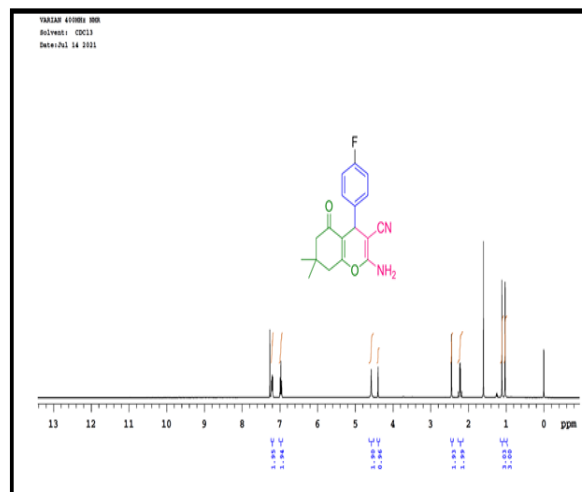
The mechanism proposed for the synthesis of chromene in presence of Ag-CP MOFs is shown in **scheme 3**. On the basis of this mechanism catalyst catalyzes the generation of olefin I that is readily prepared by the condensation reaction of aldehyde and malanonitrile to give the intermediate product II. Then the Michael addition of me with dimedone gives intermediate II. Finally the product V was obtained by intramolecular cyclization and tautomerization.



¹H NMR spectral data of synthesized chromene derivatives

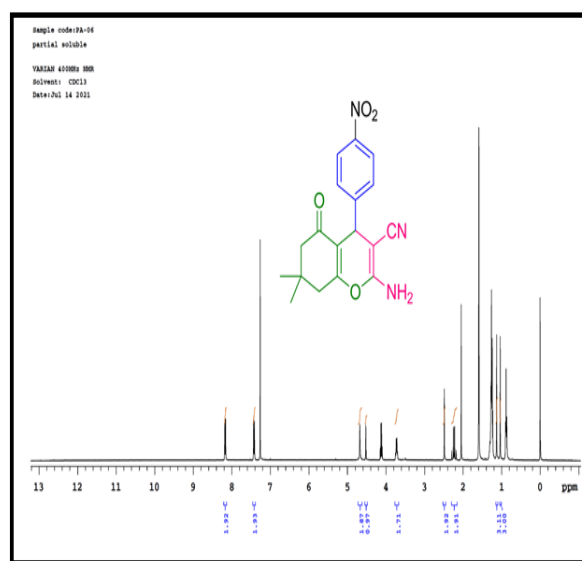
(1) ¹H NMR of 2-amino-4-(4-fluorophenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile (4b)

¹H NMR (CDCl₃, 400 MHz): δH(ppm) = 1.02 (s, 3H), 1.11 (s, 3H), 2.21-2.23 (d, 2H, J = 8Hz), 2.44 (s, 2H), 4.39 (s, 1H), 4.57 (s, 2H), 6.95-6.97 (d, 2H, J = 8Hz), 7.20-7.21 (d, 2H, J = 8Hz).



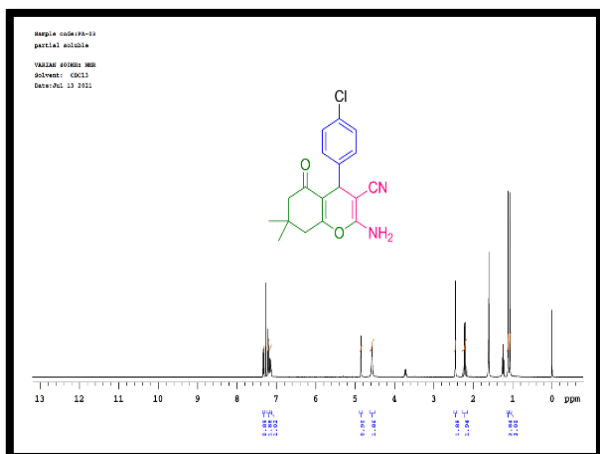
(2) ¹H NMR of 2-amino-7,7-dimethyl-4-(4-nitrophenyl)-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile (4d)

¹H NMR (CDCl₃, 400 MHz): δH(ppm) = 1.03 (s, 3H), 1.13 (s, 3H), 2.22-2.25 (d, 2H, J = 12 Hz), 2.48 (s, 2H), 3.71-3.73 (d, 2H, J = 8 Hz), 4.11-4.13 (d, 2H, J = 8 Hz), 4.52 (s, 1H), 4.67 (s, 2H), 7.41-7.43 (d, 2H, J = 8 Hz), 8.16-8.18 (d, 2H, J = 8 Hz).



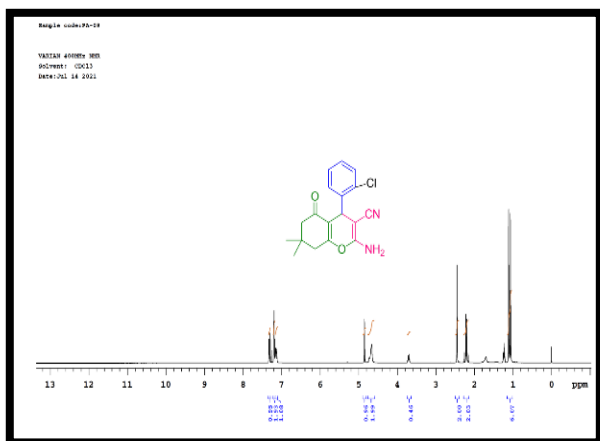
(3) ¹H NMR of 2-amino-4-(4-chlorophenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile (4g)

¹H NMR (CDCl₃, 400 MHz): δH (ppm) = 1.07 (s, 3H), 1.11 (s, 3H), 2.16-2.26 (q, 2H, J = 24Hz), 2.45 (s, 2H), 4.56 (s, 2H), 4.85 (s, 1H), 7.17 (d, 2H, J = 8Hz), 7.12-7.33 (m, 2H)



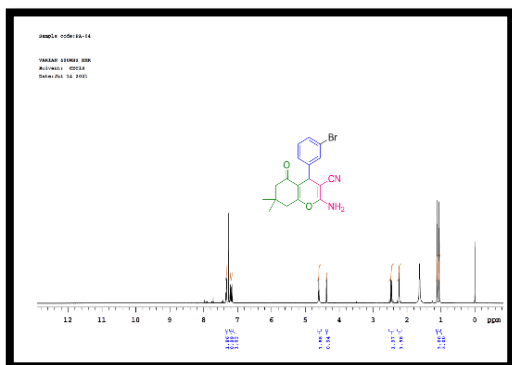
(4) ^1H NMR of 2-amino-4-(2-chlorophenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile (4f)

^1H NMR (CDCl_3 , 400 MHz): $\delta\text{H}(\text{ppm}) = 1.06$ (S, 3H), 1.11 (S, 3H), 2.20-2.22 (d, 2H, $J = 0.8\text{Hz}$), 2.45 (S, 2H), 4.64 (S, 2H), 4.66 (S, 2H), 4.84 (S, 1H), 7.11-7.20 (m, 3H), 7.31-7.33 (d, 1H, $J = 8\text{Hz}$)



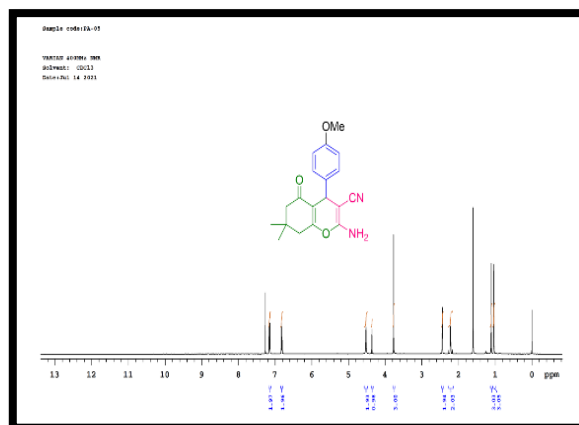
(5) ^1H NMR of 2-amino-4-(3-bromophenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile (4i)

^1H NMR (CDCl_3 , 400 MHz): $\delta\text{H}(\text{ppm}) = 1.05$ (s, 3H), 1.11 (s, 3H), 2.123-2.23 (d, 2H, $J = 2.4\text{Hz}$), 2.45-2.47 (d, 2H, $J = 8\text{Hz}$), 4.37 (s, 1H), 4.37 (s, 1H), 4.60 (s, 2H), 7.14-7.34 (m, 4H)



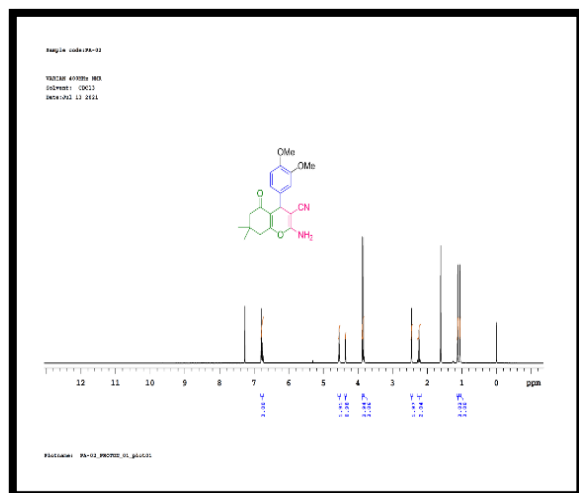
(6) ^1H NMR of 2-amino-4-(4-methoxyphenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile (4j)

^1H -NMR (CDCl_3 , 400 MHz): $\delta\text{H}(\text{ppm}) = 1.03$, (S, 3H), 1.10, (S, 3H), 2.21-2.22 (d, 2H, $J = 4\text{Hz}$), 2.44 (s, 2H), 3.76 (S, 3H), 4.35 (S, 1H), 4.36 (S, 2H), 4.52 (s, 2H), 6.80-6.82 (d, 2H, $J = 8\text{Hz}$), 7.14-7.16 (d, 2H, $J = 8\text{Hz}$).



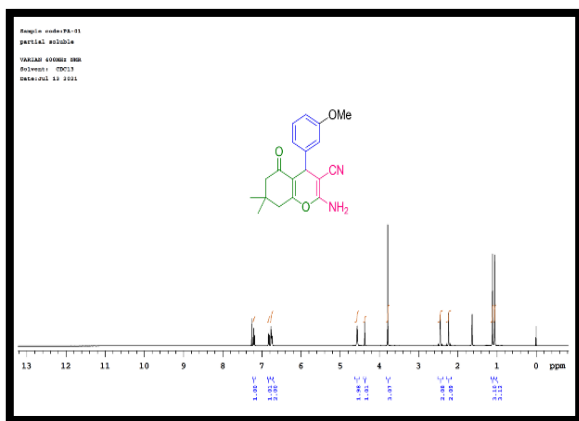
(7) ^1H -NMR of 2-amino-4-(3,4-dimethoxyphenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile (4f)

^1H -NMR (CDCl_3 , 400 MHz): $\delta\text{H}(\text{ppm}) = 1.05$ (S, 3H), 1.11 (S, 3H), 2.23-2.24 (d, 2H, $J = 4\text{Hz}$), 2.45 (S, 2H), 3.83 (S, 3H), 3.86 (S, 3H), 4.35 (S, 1H), 4.55 (S, 2H), 6.73-6.80 (m, 3H)



(8) ^1H -NMR of 2-amino-4-(3-methoxyphenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile (4g)

^1H -NMR (CDCl_3 , 400 MHz): $\delta\text{H}(\text{ppm}) = 1.05$ (S, 3H), 1.11 (S, 3H), 2.22-2.23 (d, 2H, $J = 4\text{Hz}$), 2.45 (s), 4.37 (S, 1H), 3.78 (S, 3H), 4.37 (s, 1H), 4.56 (s, 2H), 6.73-6.76 (m, 2H), 6.18-6.22 (t, 1H, $J = 8\text{Hz}$)



(9) ¹H NMR of 2-amino-4-(3,4-dichlorophenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile (4k)

¹H NMR (CDCl₃, 400 MHz): δH(ppm) = 1.06 (s, 3H), 1.11 (s, 3H), 2.20-2.22 (d, 2H, J = 8Hz), 2.45 (s, 2H), 4.58 (s, 2H), 3.71-3.72 (d, 1H, J = 4Hz), 4.65 (s, 2H), 4.80 (s, 1H), 7.14-7.20 (m, 2H), 7.34-7.34 (d, 1H, J = 2Hz).

