

SiO₂:MgMnO₃: An Efficient Heterogeneous Catalyst for One Pot Synthesis of 1*H*-Pyrazolo[1,2-*b*]phthalazine-5,10-dione Derivatives

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Received: 2 March 2020;

Accepted: 25 May 2020;

Published online: 25 September 2020;

AJC-20058

The present study deals with hydrothermal synthesis of SiO₂ composite MgMnO₃ catalyst. The obtained polycrystalline product was analyzed by using physical investigative techniques including XRD, SEM, EDAX, TEM, SAED and BET surface area. The product corresponded to average particle size of 100 nm by TEM images. The BET surface area was found 234.38 cm²/g for SiO₂ composite MgMnO₃ catalyst which indicates a good catalytic property. The synthesized catalyst was applied for the synthesis of 1*H*-pyrazolo[1,2-*b*]phthalazine-5,10-dione in presence of ethanol as a solvent at 80 °C. The current procedure and catalyst offers the gains of clean reaction, short reaction time, high yield, easy purification and financial availability of the catalyst.

Keywords: 1*H*-Pyrazolo[1,2-*b*]phthalazine-5,10-dione, Multicomponent reaction, SiO₂:MgMnO₃ catalyst, Short reaction time.

INTRODUCTION

Hydrazine heterocyclic components have attracted considerable advertece, because they show enough pharmacological properties and biological activities [1-5]. Phthalazine derivatives are an important group of heterocycles which have been subject to broad study in the past years. Among these phthalazines, 4-substituted phthalazines have been reported as active anticancer [6], antimicrobial [7], antifungal [8], anti-inflammatory [9] and anticonvulsant [10]. Moreover phthalazine derivatives are also found to possess cardiotonic [11] and vasorelaxant [12]. In addition, a number of 2,3-dihydrophthalazine-1,4-dione derivatives are well known to be active as potential anticonvulsant [13]. In view of above mentioned realities and continuation of our research interest for the synthesis of biologically active heterocycles [14].

Multicomponent reactions (MCRs) are one of the most efficient tool for synthesize diverse and complex organic molecule in one pot synthesis. Multicomponent reactions are very significant and contribute to an ideal synthesis, to increase in molecular complexity, high atom efficiency and impressive selectivity within single step in order to avoid time consuming and costly procedures for the purification of various precursors

and isolation of intermediate and main products [15,16]. Therefore the development of new procedure for multicomponent reactions is very important in the field of organic and medicinal chemistry.

The synthesis of 1*H*-pyrazolo[1,2-*b*]phthalazine-5,10-dione derivatives *via* the three-component coupling of aldehydes, malononitrile or ethyl cyanoacetate and phthalhydrazide has been reported using MCRs in occurrence of diverse catalysts including PTSA/[Bmim]Br [17], Et₃N/EtOH [18], [Bmim]OH/MW [19], (DBU)[CH₃COO] [20], AL-KIT-6 [21], NiCl₂·6H₂O (ethanol/reflux) [22] InCl₃ [23]. But current methodologies are suffered from numerous disadvantages such as longer reaction time, high temperature, harsh reaction condition, use of toxic and expensive catalyst, lack of recyclability of catalyst and so forth. Accordingly, there is a scope to develop another methods for the synthesis of 1*H*-pyrazolo[1,2-*b*]phthalazine-5,10-diones under environmentally caring conditions. Heterogeneous catalyst has received remarkable interest, both from a scientific and an industrial viewpoint. Heterogeneous catalysis is leading to a deeper understanding of how chemical reaction takes place at surface [22-24]. Nowadays, nanoparticles have drawn major attention because they connect the gap between bulk materials and atomic or molecular structures.

Research on composite catalyst has focused on particle size in order to correlating the catalytic activity, many other aspects such as geometry, composition and chemical/physical environment can play a role in determining the catalytic activity. Composite particulate $\text{SiO}_2\text{:MgMnO}_3$ is one of the most versatile and technologically important materials because of its catalytic behaviour. On account of these properties, as a part of ongoing program on the development of novel methods in organic synthesis, herein, use of $\text{SiO}_2\text{:MgMnO}_3$ as an efficient catalyst for the synthesis of one pot synthesis 1*H*-pyrazolo[1,2-*b*]phthalazine derivative-5,10-dione by the four-component condensation reaction of phthalic anhydride, hydrazine monohydrate, benzaldehyde and ethyl cyanoacetate in the presence of ethanol as solvent (**Scheme-I**) is reported.

EXPERIMENTAL

All reagents were purchased and used without further purification: silica (SiO_2 , Merck, 99.00%), MgMnO_3 (synthesized by earlier reported procedure) [25] and sodium hydroxide (NaOH, Merck, 99.90%).

Synthesis of $\text{SiO}_2\text{:MgMnO}_3$: The silica composite MgMnO_3 catalyst was prepared by mixing essential amount of SiO_2 solution (1 mol) with synthesized MgMnO_3 powder (1 mol) in presence of buffer solution. The slurry obtained was stirred for 1 h and shifted into steel lined Teflon autoclave and placed in the oven at 120 °C for 24 h. The precipitate obtained was filtered washed with distilled water and dried at 100 °C for 6 h. The polycrystalline product was directly kept in the furnace for calcination at 450 °C for 4 h.

Characterization: The pure products obtained were characterized by various analytical techniques. The XRD pattern obtained was recorded on a multipurpose X-ray diffractometer (Philips-1710 diffractometer with $\text{CuK}\alpha$, $\lambda = 1.5406 \text{ \AA}$). The surface morphology and chemical stoichiometry of synthesized catalyst were evaluated by scanning electron microscope-JSM-6300 (JEOL) and energy dispersive spectrometer-JED-2300LA (JEOL). The structure and particle size of the synthesized materials were studied using TEM with SAED on CM-200, Phillips microscope. The BET surface area was measured by N_2 adsorption-desorption isotherm and was carried out on Quantachrome Autosorb Automated Gas Sorption System Autosorb-1, NOVA-1200 and Mercury PorosimeterAutosorb-1c.

General procedure for the synthesis of 1*H*-pyrazolo[1,2-*b*]phthalazine-5,10-dione (5a-h**):** In a 25 mL round-bottom flask, mixture of phthalic anhydride (**1**) (0.57 g, 1 mmol), hydrazine hydrate (**2**) (0.123 g, 1 mmol), ethylcyanoacetate

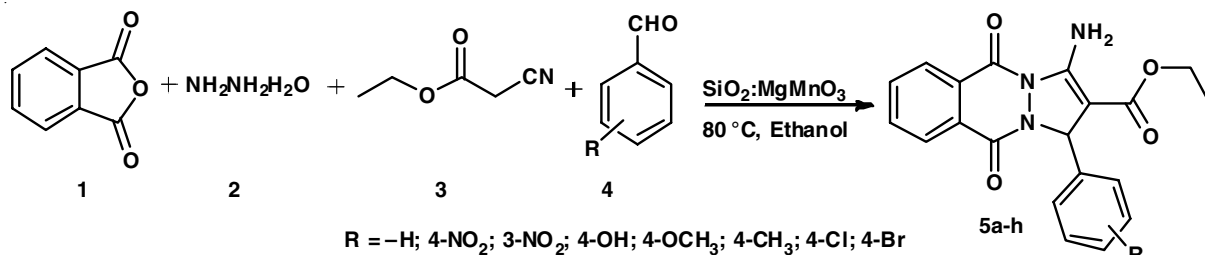
(0.34 g, 1 mmol), benzaldehyde (**4**) (0.30 g, 2 mmol) in presence of $\text{SiO}_2\text{:MgMnO}_3$ catalyst (0.6 mol) were taken. The reaction mixture was heated at 80 °C in presence of ethanol for 20 min. After completion, the reaction mixture was cooled to room temperature and then poured over crushed ice, stirred for 10-15 min, precipitated product was filtered, washed with water, dried and recrystallized (**Scheme-I**). All the synthesized compounds (**5a-h**) were characterized by IR, ^1H & ^{13}C NMR and LCMS analysis.

Spectral data

Ethyl 3-amino-5,10-dihydro-5,10-dioxo-1-phenyl-1*H*-pyrazolo[1,2-*b*]phthalazine-2-carboxylate (5a**):** IR (KBr, ν_{max} , cm^{-1}): 3298 ($-\text{NH}_2$), 3150 ($=\text{C}-\text{H}$), 1698 ($\text{C}=\text{O}$), 1653 ($\text{C}=\text{C}$), 1554 ($\text{C}-\text{O}$), 1211 ($\text{C}-\text{N}$); ^1H NMR (300 MHz, $\text{DMSO}-d_6$): 1.23 (3H, t, $-\text{CH}_3$), 2.34 (2H, q, $-\text{CH}_2$), 5.85 (1H, s, $-\text{CH}$), 7.19–7.34 (4H, m, $J = 7.7$ & 2.4 Hz, Ar-H), 7.76–8.05 (5H, m, $J = 7.8$ & 2.2 Hz, Ar-H), 10.1 (2H, s, $-\text{NH}_2$) ppm; ^{13}C NMR (75 MHz, $\text{DMSO}-d_6$): δ 21.9 ($-\text{CH}_3$), 65.2 ($-\text{CH}_2$), 98.5 ($-\text{CH}_3$), 121.0 (Ar-CH), 128.7 (Ar-CH), 128.8 (Ar-CH), 129.2 (Ar-CH), 129.8 (Ar-CH), 130.0 (Ar-CH), 130.3 (Ar-CH), 130.5 (Ar-CH), 130.5 (Ar-CH), 131.8 (Ar-CH), 133.2 (Ar-CH), 134.5 (Ar-CH), 151.7 ($-\text{C}=\text{O}$), 157.2 ($-\text{C}=\text{O}$), 159.6 ($-\text{C}=\text{O}$); m.f.: $\text{C}_{20}\text{H}_{17}\text{N}_3\text{O}_4$; Calculated MS: 363.12; EI-MS (m/z): 363.37 ($\text{M}+1$).

Ethyl 3-amino-5,10-dihydro-5,10-dioxo-1-*p*-nitro-1*H*-pyrazolo[1,2-*b*]phthalazine-2-carboxylate (5b**):** IR (KBr, ν_{max} , cm^{-1}): 3286 ($-\text{NH}_2$), 1698 ($\text{C}=\text{O}$), 1634 ($\text{C}=\text{C}$), 1558 ($\text{C}=\text{O}$), 1254 ($\text{C}-\text{N}$); ^1H NMR (300 MHz, $\text{DMSO}-d_6$): 1.54 (3H, t, $-\text{CH}_3$), 2.42 (2H, q, $-\text{CH}_2$), 6.01 (1H, s, $-\text{CH}$), 7.04–7.45 (4H, m, $J = 8.0$ & 2.1 Hz, Ar-H), 7.56–7.88 (4H, m, $J = 7.8$ & 2.2 Hz, Ar-H) 10.8 (2H, s, $-\text{NH}_2$); ^{13}C NMR (75 MHz, $\text{DMSO}-d_6$): δ 19.7 ($-\text{CH}_3$), 53.9 ($-\text{CH}_2$), 79.8 ($-\text{CH}$), 110.2 ($-\text{C}$), 119.2 (Ar-CH), 126.5 (Ar-CH), 129.1 (Ar-CH), 131.7 (Ar-CH), 132.1 (Ar-CH), 132.8 (Ar-CH), 134.7 (Ar-CH), 134.9 (Ar-CH), 137.8 (Ar-CH), 137.9 (Ar-CH), 140.2 (Ar-CH), 140.5 (Ar-CH), 156.7 ($-\text{C}=\text{O}$), 161.1 ($-\text{C}=\text{O}$), 162.4 ($-\text{C}=\text{O}$); m.f.: $\text{C}_{20}\text{H}_{16}\text{N}_4\text{O}_6$; Calculated MS: 408.1; EI-MS (m/z): 408.11 ($\text{M}+1$).

Ethyl 3-amino-5,10-dihydro-5,10-dioxo-1-*m*-nitro-1*H*-pyrazolo[1,2-*b*]phthalazine-2-carboxylate (5c**):** IR (KBr, ν_{max} , cm^{-1}): 3332 ($-\text{NH}_2$), 1693 ($\text{C}=\text{O}$), 1634 ($\text{C}=\text{C}$), 1540 ($\text{C}=\text{O}$), 1345 ($-\text{NO}_2$), 1234 ($\text{C}-\text{N}$); ^1H NMR (300 MHz, $\text{DMSO}-d_6$): 1.31 (3H, t, $-\text{CH}_3$), 2.39 (2H, q, $-\text{CH}_2$), 5.98 (1H, s, $-\text{CH}$), 6.8 (2H, s, $-\text{NH}_2$), 7.07–7.39 (4H, m, $J = 7.4$ & 2.4 Hz, Ar-H), 7.45–7.89 (4H, m, $J = 8.0$ & 2.2 Hz, Ar-H); ^{13}C NMR (75 MHz, $\text{DMSO}-d_6$): δ 23.9 ($-\text{CH}_3$), 51.8 ($-\text{CH}_2$), 77.2 ($-\text{CH}$), 99.5



Scheme-I: Synthesis of 1*H*-pyrazolo[1,2-*b*]phthalazine-5,10-dione derivatives using $\text{SiO}_2\text{:MgMnO}_3$ catalyst

(-C-), 123.2 (Ar-CH), 129.9 (Ar-CH), 129.9 (Ar-CH), 131.6 (Ar-CH), 131.8 (Ar-CH), 134.3 (Ar-CH), 136.4 (Ar-CH), 136.5 (Ar-CH), 137.5 (Ar-CH), 137.8 (Ar-CH), 137.9 (Ar-CH), 139.7 (Ar-CH), 140.5 (Ar-CH), 155.7 (-C=O), 158.4 (-C=O), 159.6 (-C=O); m.f.: C₂₀H₁₆N₄O₆; Calculated MS: 408.1; EI-MS (*m/z*): 408.11 (M+1).

Ethyl 3-amino-5,10-dihydro-5,10-dioxo-1-*p*-hydroxy-1*H*-pyrazolo[1,2-*b*]phthalazine-2-carboxylate (5d): IR (KBr, ν_{\max} , cm⁻¹): 3334 (-NH₂), 3234 (-OH), 1684 (C=O), 1554 (C=C) 1543 (C=O), 1276 (C-N); ¹H NMR (400 MHz, DMSO-*d*₆): δ 1.16 (3H, t, -CH₃), 2.12 (2H, q, -CH₂), 5.82 (1H, s, -CH), 6.2 (1H, -OH), 6.80-7.12 (2H, d, *J* = 7.8 & 2.2Hz, Ar-H), 7.32-7.74 (2H, d, *J* = 7.8 & 2.2Hz, Ar-H), 7.95-8.24 (4H, m, *J* = 8.1 & 2.1Hz, Ar-H), 9.51 (2H, s, -NH₂); ¹³C NMR (100 MHz, DMSO-*d*₆): δ 18.5 (-CH₃-), 61.4 (-CH₂-), 92.6 (-CH-), 115.0 (-C-), 116.2 (Ar-CH), 126.6 (Ar-CH), 127.3 (Ar-CH), 128.3 (Ar-CH), 128.6 (Ar-CH), 128.8 (Ar-CH), 133.6 (Ar-CH), 134.5 (Ar-CH), 150.5 (Ar-CH), 153.5 (-C=O), 156.6 (-C=O), 157.6 (-C=O); m.f.: C₂₀H₁₇N₃O₅; Calculated MS: 379.21; EI-MS (*m/z*): 379.11 (M+1).

Ethyl 3-amino-5,10-dihydro-5,10-dioxo-1-*p*-methoxy-1*H*-pyrazolo[1,2-*b*]phthalazine-2-carboxylate (5e): IR (KBr, ν_{\max} , cm⁻¹): 3361 (-NH₂), 1690 (C=O), 1645 (C=C) 1569 (C=O), 1298 (C-N); ¹H NMR (400 MHz, DMSO-*d*₆): δ 1.08 (3H, t, -CH₃), 2.12 (3H, s, -CH₃), 3.28 (2H, s, -CH₂), 5.67 (1H, s, -CH), 7.14-7.21 (2H, d, *J* = 7.8 & 2.2Hz, Ar-H), 7.34-7.43 (2H, d, *J* = 7.8 & 2.2Hz, Ar-H), 7.94-8.25 (4H, dd, *J* = 7.8 & 2.2Hz, Ar-H); ¹³C NMR (100 MHz, DMSO-*d*₆): δ 20.9 (-CH₃-), 34.4 (-CH₃-), 55.8 (-CH₂-), 82.3 (-CH-), 113.1 (-C-), 123.4 (Ar-CH), 127.4 (Ar-CH), 127.6 (Ar-CH), 127.9 (Ar-CH), 128.1 (Ar-CH), 128.7 (Ar-CH), 130.2 (Ar-CH), 130.8 (Ar-CH), 133.3 (Ar-CH), 134.6 (Ar-CH), 135.0 (Ar-CH), 136.5 (Ar-CH), 153.0 (-C=O), 154.7 (-C=O), 157.0 (-C=O); m.f.: C₂₁H₁₉N₃O₅; Calculated MS: 393; EI-MS (*m/z*): 393.87 (M+1).

Ethyl 3-amino-5,10-dihydro-5,10-dioxo-1-*p*-tolyl-1*H*-pyrazolo[1,2-*b*]phthalazine-2-carboxylate (5f): IR (KBr, ν_{\max} , cm⁻¹): 3357 (-NH₂), 1705 (C=O), 1665 (C=C), 1580 (C-O), 1242 (C-N); ¹H NMR (400 MHz, DMSO-*d*₆): δ 1.02 (3H, t, -CH₃), 1.23 (3H, t, -CH₃), 2.44 (2H, q, -CH₂), 5.27 (2H, s, -CH), 5.95 (1H, s, -NH₂), 7.09-7.24 (2H, d, *J* = 7.8 & 2.2Hz, Ar-H), 7.34-7.54 (2H, d, *J* = 7.8 & 2.2Hz, Ar-H), 7.81-8.46 (4H, dd, *J* = 8.2 & 2.3Hz, Ar-H); ¹³C NMR (100 MHz, DMSO-*d*₆): δ 16.9 (-CH₃-), 24.4 (-CH₃-), 61.3 (-CH₂-), 93.2 (-CH-), 112.1 (C-), 122.3 (Ar-CH), 127.2 (Ar-CH), 127.4 (Ar-CH), 127.8 (Ar-CH), 128.2 (Ar-CH), 128.6 (Ar-CH), 128.9 (Ar-CH), 131.4 (Ar-CH), 134.0 (Ar-CH), 134.6 (Ar-CH), 135.6 (Ar-CH), 136.3 (Ar-CH), 154.0 (-C=O), 154.5 (-C=O), 157.3 (-C=O); m.f.: C₂₁H₁₉N₃O₄; Calculated MS: 377; EI-MS (*m/z*): 378.21 (M+1).

Ethyl 3-amino-5,10-dihydro-5,10-dioxo-1-*p*-chloro-1*H*-pyrazolo[1,2-*b*]phthalazine-2-carboxylate (5g): IR (KBr, ν_{\max} , cm⁻¹): 3245 (-NH₂), 1708 (C=O), 1668 (C=C), 1521 (C-O), 1340 (C-N), 710 (C-Cl); ¹H NMR (300 MHz, DMSO-*d*₆): 1.09 (3H, t, -CH₃), 2.21 (2H, q, -CH₂), 5.43 (1H, s, -CH), 7.23-7.58 (4H, dd, *J* = 7.4 & 2.1Hz, Ar-H), 7.67-8.01 (4H, dd, *J* = 8.2 & 2.2Hz, Ar-H), 9.8 (2H, s, -NH₂); ¹³C NMR (75

MHz, DMSO-*d*₆): δ 23.5 (-CH₃-), 67.3 (-CH₂-), 89.3 (-CH-), 113.6 (Ar-CH), 118.5 (Ar-CH), 121.2 (Ar-CH), 123.6 (Ar-CH), 126.3 (Ar-CH), 128.0 (Ar-CH), 128.8 (Ar-CH), 129.5 (Ar-CH), 131.1 (Ar-CH), 131.4 (Ar-CH), 131.9 (Ar-CH), 134.4 (Ar-CH), 134.9 (Ar-CH), 145.2 (-C=O), 147.2 (-C=O), 148.6 (-C=O); m.f.: C₂₀H₁₆N₃O₄Cl; Calculated MS: 397.23; EI-MS (*m/z*): 399.17 (M+1).

Ethyl 3-amino-5,10-dihydro-5,10-dioxo-1-*p*-bromo-1*H*-pyrazolo[1,2-*b*]phthalazine-2-carboxylate (5h): IR (KBr, ν_{\max} , cm⁻¹): 3298 (-NH₂), 1703 (C=O), 1645 (C=C), 1590 (C-O), 1234 (C-N), 687 (C-Br); ¹H NMR (300 MHz, DMSO-*d*₆): 1.14 (3H, t, -CH₃), 2.56 (2H, q, -CH₂), 5.63 (1H, s, -CH), 7.23-7.56 (4H, dd, *J* = 8.2 & 2.3Hz, Ar-H), 7.81-8.11 (4H, dd, *J* = 8.2 & 2.3Hz, Ar-H), 10.8 (2H, s, -NH₂); ¹³C NMR (75 MHz, DMSO-*d*₆): δ 23.7 (-CH₃-), 61.2 (-CH₂-), 94.7 (-CH-), 118.3 (Ar-CH), 121.2 (Ar-CH), 124.2 (Ar-CH), 127.8 (Ar-CH), 128.8 (Ar-CH), 131.0 (Ar-CH), 131.3 (Ar-CH), 132.1 (Ar-CH), 134.5 (Ar-CH), 134.8 (Ar-CH), 135.1 (Ar-CH), 135.7 (Ar-CH), 136.1 (Ar-CH), 143.2 (-C=O), 147.8 (-C=O), 159.9 (-C=O); m.f.: C₂₀H₁₆N₃O₄Br; Calculated MS: 441.23; EI-MS (*m/z*): 442.17 (M+1).

RESULTS AND DISCUSSION

Fig. 1 shows XRD pattern of SiO₂:MgMnO₃ powder formed after heating. The crystal structure of SiO₂:MgMnO₃ is cubic in nature and all the *d*-line patterns of MgMnO₃ was match with JCPDS data Card No-19-3456. Fig. 1 gives XRD pattern for SiO₂:MgMnO₃ having 2 θ values with (hkl) plane are 26.3 (111), 32.5 (100), 36.8 (200), 56.2 (202) 56.3 (222), 64.4 (200), 65.85 (100), 77.54 (200). The recorded XRD pattern shows there is no any amorphous phase found and it reveals that product is highly polycrystalline with cubic in nature.

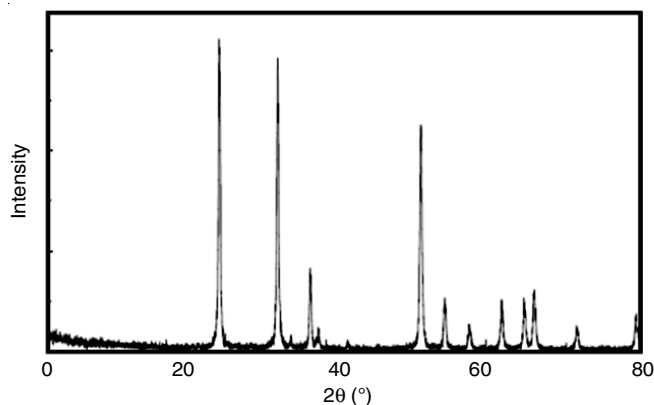
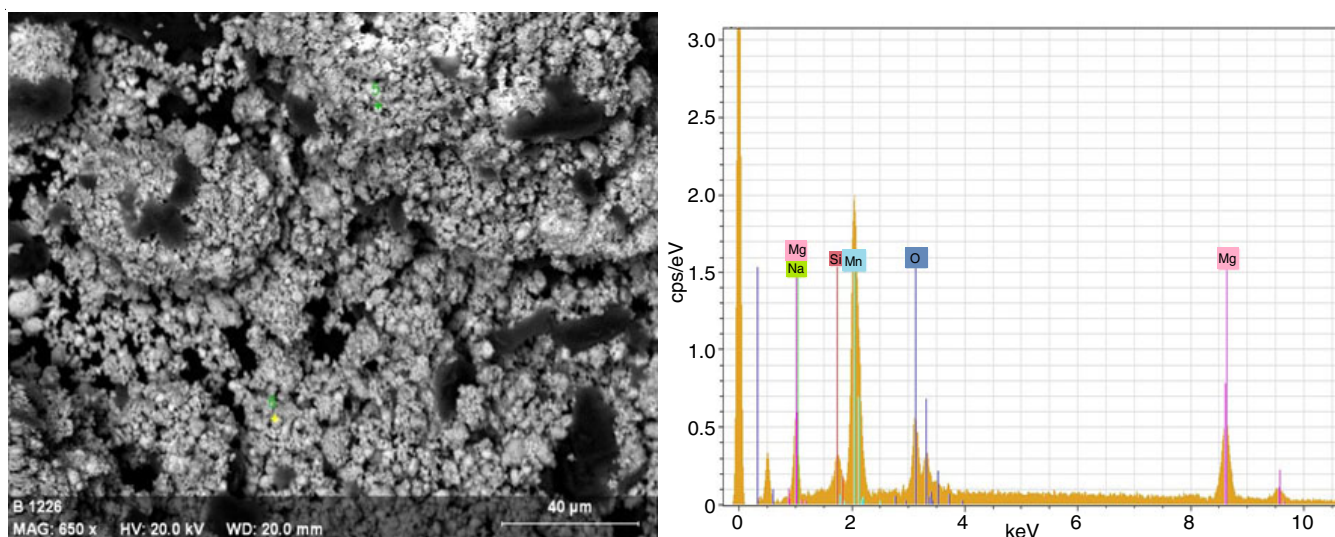


Fig. 1. XRD analysis of SiO₂:MgMnO₃ catalyst

The surface morphology and associated chemical composition of the synthesized SiO₂:MgMnO₃ catalyst was analyzed by SEM coupled with EDAX as depicted in Fig. 2. Fig. 2 shows that particles are uniformly distributed showing agglomerations. The EDAX data furnishes information about elemental composition associated with the image of SiO₂:MgMnO₃ catalyst.

The TEM image along with the selected area of the diffraction pattern (SAED) recorded for the sample corresponding

Fig. 2. SEM analysis of $\text{SiO}_2\text{:MgMnO}_3$ catalyst

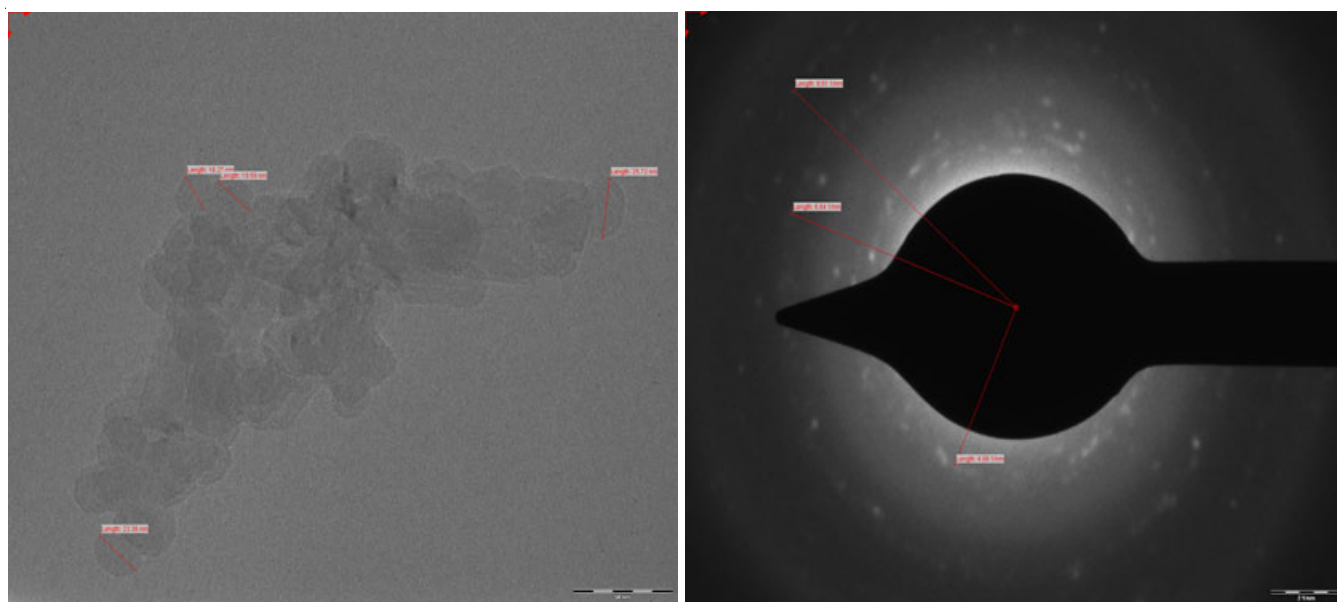
to $\text{SiO}_2\text{:MgMnO}_3$ is given in Fig. 3. The TEM reveals that, the nanoparticles are elongated; however there are several cubic-shaped crystallites. The dark spot in the TEM micrograph can be alluded to $\text{SiO}_2\text{:MgMnO}_3$ nanoparticles as SAED pattern associated with such spots reveals occurrence of cubic $\text{SiO}_2\text{:MgMnO}_3$ in total agreement with the XRD data. The average size of the $\text{SiO}_2\text{:MgMnO}_3$ nanocrystallites were found to be 100 nm.

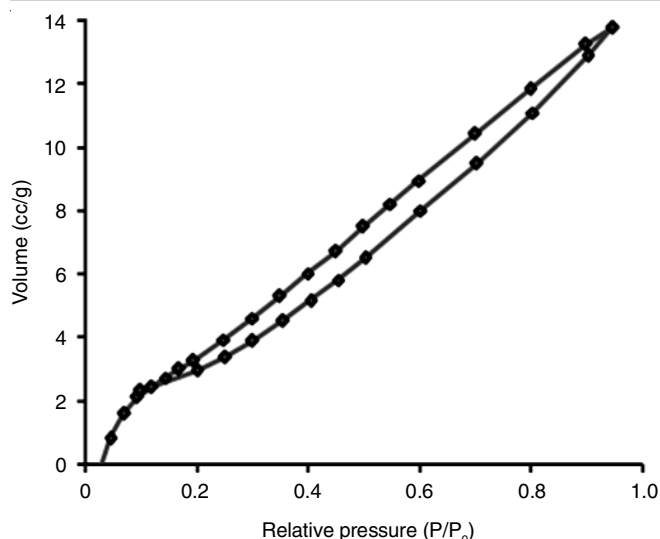
The detailed information about surface area (BET), mesoporous volume and pore size distribution arises from N_2 -adsorption/desorption isotherm method. This method leads to the identification of the isotherm profile as type IV in the BDDT system which is typical for mesoporous material. The BJH pore size distribution demonstrates that all the samples have narrow pore diameter range. Surface area of material plays an important role in catalysis. The BET surface area (S_{BET}), pore volume (V_p), pore diameter (D_p) and other parameters

are recorded. In the present investigation the typical nitrogen adsorption/desorption isotherm and BJH pore distribution of synthesized $\text{SiO}_2\text{:MgMnO}_3$ are depicted in Fig. 4. A careful inspection shows that the surface area for $\text{SiO}_2\text{:MgMnO}_3$ is $234.38 \text{ m}^2/\text{g}$ and it founds highest, the average pore volume and diameter are 0.03498 cc/g and 56.87 \AA . This clearly gives evidence that the grafting of $\text{SiO}_2\text{:MgMnO}_3$ shows increase in large surface area.

Our initial experiments were focused on the one pot, four component reactions of ethyl cyanoacetate, hydrazine monohydrate, benzaldehyde and phthalic anhydride using different catalysts in presence of ethanol and the results are listed in Table-1. It was found that $\text{SiO}_2\text{:MgMnO}_3$ showed better catalytic activity than MgMnO_3 catalyst. When the reaction was performed in absence of catalyst no product formation takes place.

To get better yield of product the amount of catalyst were optimized for the reaction such as 0.2, 0.4, 0.6, 0.8, 1.0 mol.

Fig. 3. TEM and SAED analysis of $\text{SiO}_2\text{:MgMnO}_3$ catalyst

Fig. 4. BET analysis of SiO₂:MgMnO₃ catalyst

| Entry | Catalyst | Time (min) | Yield (%) |
|-------|--------------------------------------|------------|-------------|
| 1 | No catalyst | 120 | No reaction |
| 2 | MgMnO ₃ | 60 | 67 |
| 3 | SiO ₂ :MgMnO ₃ | 20 | 93 |
| 4 | SiO ₂ | 60 | 57 |

When 0.6 mol of SiO₂:MgMnO₃ was used, the reaction proceeded efficiently and gave the product **5a** with 93% yield (Table-2, entry 3). Moreover, we found that the yields were obviously affected by the amount of SiO₂:MgMnO₃ loaded. When 0.2, 0.4, 0.6, 0.8 and 1.0 mol, of SiO₂:MgMnO₃ was used, the yields were 58, 76, 93, 92 and 90%, respectively (Table-2, entries 1-5).

| Entry | Catalyst (mol) | Time (min) | Yield (%) |
|-------|----------------|------------|-----------|
| 1 | 0.2 | 60 | 58 |
| 2 | 0.4 | 60 | 76 |
| 3 | 0.6 | 20 | 93 |
| 4 | 0.8 | 20 | 92 |
| 5 | 1.0 | 20 | 90 |

Therefore, 0.6 mol of SiO₂:MgMnO₃ was sufficient to push the reaction forward and further increasing the amount of SiO₂:MgMnO₃ did not increase the yields. In addition, no desired product was detected in the absence of the catalyst (Table-1, entry 1). The above results showed that SiO₂:MgMnO₃ was essential in the reaction and the best results were obtained when the reaction was carried out with 0.6 mol of SiO₂:MgMnO₃ using ethanol at 80 °C. Then, we examined the effect of solvents for above reaction.

The results of Table-3 indicate that solvents affected the efficiency of the reaction. Poor yields were obtained in presence of acetonitrile, DMF, water and solvent free condition (Table-3, entries 1-5). Better yields were obtained in presence of ethanol (Table-3, entry 4).

| Entry | Solvent | Time (min) | Yield (%) |
|-------|------------------|------------|-----------|
| 1 | No solvent | 120 | 38 |
| 2 | MeCN | 120 | 58 |
| 3 | DMF | 90 | 60 |
| 4 | EtOH | 20 | 93 |
| 5 | H ₂ O | 120 | 30 |

To study the generality of this protocol, we extended our study with different aromatic aldehydes to prepare a series of 1*H*-pyrazolo[1,2-*b*]phthalazine-5,10-dione (**5a-h**, Table-4). In case of aromatic aldehydes, products were obtained in good to excellent yields while aliphatic aldehydes results poor yields.

| Entry | Compound | -R | Time (min) | Yield (%) |
|-------|-----------|--------------------|------------|-----------|
| 1 | 5a | -H | 20 | 93 |
| 2 | 5b | 4-NO ₂ | 25 | 92 |
| 3 | 5c | 3-NO ₂ | 25 | 93 |
| 4 | 5d | 4-OH | 25 | 90 |
| 5 | 5e | 4-OCH ₃ | 25 | 93 |
| 6 | 5f | 4-CH ₃ | 20 | 89 |
| 7 | 5g | 4-Cl | 25 | 90 |
| 8 | 5h | 4-Br | 25 | 87 |

Conclusion

In the present work, we described an efficient and one-pot synthesis of 1*H*-pyrazolo[1,2-*b*]phthalazine-5,10-diones by the four-component condensation reaction of phthalic anhydride, hydrazine monohydrate, benzaldehyde and ethyl cyanoacetate using ethanol at 80 °C with high yields. The benefits offered by this method include, short reaction times, non-toxic, excellent yields, a simple procedure, easy workup, environmentally benign nature make it an attractive process and the employment of a cost-effective catalyst.

ACKNOWLEDGEMENTS

Authors are thankful to the SAIF, IIT Powai, Mumbai and SAIF, Punjab University, Chandigarh for providing valuable characterization facility for the synthesized compounds.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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