STM JOURNALS

Journal of
Modern Chemistry &
Chemical Technology

ISSN: 2229-6999 (Online)
ISSN: 2321-5208 (Print)
Volume 17, Issue 3, 2026
September–December
DOI (Journal): 10.37591/JoMCCT

https://journals.stmjournals.com/jomcct

Research JoMCCT

Studies on Co-Mo Nitride Incorporated Mesoporous Alumina for the Oxidative Dehydrogenation of Ethylbenzene to Styrene

J. Madhavi*

Abstract

The oxidative dehydrogenation of ethylbenzene to styrene using oxidants is a beneficial process compared to the direct ethylbenzene dehydrogenation in the presence of steam at higher temperatures. The oxidative dehydrogenation process is free from thermodynamic limitations and yields greater EB conversions at lower temperatures. In the present study, the oxidative dehydrogenation of ethylbenzene to styrene was carried out over 10 and 15wt% Co-Mo nitride incorporated on mesoporous alumina catalysts in the presence of CO_2 and N_2 gas flows at 873 K. 10wt% Co-Mo nitride on meso-alumina catalyst showed greater EB conversion (82.1%) and stable activity compared to 15wt% Co-Mo nitride on meso-alumina. Time-on-stream studies were conducted on 10 and 15wt% Co-Mo nitride on meso-alumina catalyst at 873 K for 10h in the presence of CO_2 and N_2. And it was noticed that the 10wt% Co-Mo nitride on meso- alumina catalyst showed stable activity and increase in the styrene selectivity for 10h compared to the 15wt% Co-Mo nitride on meso- alumina catalyst. The prepared catalysts were analyzed using X-ray diffraction, temperature-programmed reduction, and N_2 adsorption-desorption isotherms and these studies confirmed that the high surface area and greater dispersion of the active phase (Co-Mo nitride) on meso-alumina are responsible for the greater EB conversions in the case of 10wt% Co-Mo nitride on meso-alumina.

Keywords: Dehydrogenation, meso-porous alumina, Co-Mo nitride, EB conversion, styrene

INTRODUCTION

Styrene, which is used for the synthesis of polystyrene and synthetic rubbers, is commercially produced via the dehydrogenation of ethylbenzene over potassium-promoted iron oxide catalysts [1]. The current global production capacity of styrene is 43 million tonnes per year and is expected to increase further. Consequently, there is a need to develop efficient catalysts and processes to meet the demands of the growing global population [2–4]. The development of suitable catalysts is essential to minimize the problems associated with commercial K-promoted Fe_2O_3 catalysts [5]. Various catalysts have been tested and proven to be active for the dehydrogenation of EB, such as alkali-promoted active metals, hydrotalcite compounds, metal oxides, mixed metal oxides and spinel oxides, zeolites, pillared clay, and activated carbon. Although these catalysts exhibited greater conversion at the initial stage, they deactivated within hours. Mesoporous silica and ordered alumina materials have been used as catalyst supports for dehydrogenating hydrocarbons to reduce the extent of catalyst deactivation [6, 7]. Their uniformly ordered channels, controllable pore sizes, and high surface areas disperse the

***Author for Correspondence**
J. Madhavi
E-mail: madhavi0521@gmail.com

Associate Professor, Department of Chemistry, Government Degree College (Autonomous) Paloncha, Bhadradri Kothagudem, Telangana

Received Date: August 6, 2026
Accepted Date: September 8, 2026
Published Date: October 29, 2026

Citation: J. Madhavi. Studies on Co-Mo Nitride Incorporated Mesoporous Alumina for the Oxidative Dehydrogenation of Ethylbenzene to Styrene. Journal of Modern Chemistry & Chemical Technology. 2026; 17(3): 22–26p.

© STM Journals 2026. All Rights Reserved

catalytically active entities against sintering. The dehydrogenation of EB is carried out under a stream of different oxidants, such as CO_2, N_2O, and O_2, to shift the equilibrium, remove hydrogen, and supply reactive oxygen [8–10].

Among mesoporous materials, mesoporous alumina possesses a higher surface area and pore volume than commercial γ-alumina. Owing to these properties, a greater number of active sites are available for the reactants, and therefore, higher conversions are expected. In this study, a Co-Mo nitride catalyst (Co_3Mo_3N) was incorporated into mesoporous alumina to achieve enhanced EB conversion and stable activity. The dehydrogenation of EB was studied using over 10wt% and 15wt% Co_3Mo_3N supported on mesoporous alumina in a fixed bed reactor at 873 K under CO_2 and N_2 flows.

EXPERIMENTAL

Preparation of Mesoporous Alumina (MA)

Mesoporous alumina was synthesized via the sol–gel method as described by Zhang et al. [11]. Initially, the solution was stirred at ambient temperature for 9 hours, followed by heating at 343 K for 24 hours and subsequently at 373 K for 2 hours. The gel was then transferred to an autoclave and subjected to heating at 393 K for 12 hours. The final gel underwent washing with ethanol, drying, and calcination at 873 K for 3 hours.

Preparation of Co-Mo nitride supported catalysts

Mesoporous alumina-supported Co_3Mo_3N catalysts with 10 and 15 wt% of Co_3Mo_3N were prepared by impregnating the support with an aqueous solution containing requisite amounts of Co $(NO_3)_26H_2O$, $(NH_4)_6Mo_7O_{24}\bullet 4H_2O$, and HMT, followed by aerial evaporation for 24 h and further drying at 313 K for 6 h. The solid was subjected to heating under inert gas flow (Argon/Helium/Nitrogen), following the procedure established for the synthesis of Co_3Mo_3N [12, 13]. The meso-alumina supported catalysts with 10 and 15wt% Co_3Mo_3N were designated as 10BMN/MA and 15BMN/MA, respectively.

Catalyst Characterization

All the catalysts were analyzed using methods and procedures described in the literature [13].

Catalyst Activity study

The catalytic activity was performed in a fixed- bed quartz reactor at normal pressure. About 1 g of catalyst was placed in the reactor at the center by using quartz wool and was pre-treated at 873 K for 30 min in N_2 flow (30 ml min^{-1}). A time-on-stream study was conducted in CO_2 and N_2 gas flows with a flow rate of 30 cm^3 min^{-1}. Ethylbenzene was introduced using a liquid feed pump (M/s). B. Braun, Germany) at a feed rate of 8.2 m.mol h^{-1}. The products were collected at regular intervals in an ice-cold trap and analyzed using a flame ionization detector (FID)-equipped gas chromatograph, GC-17A (M/s. Shimadzu Instruments, Japan) using a capillary column, OV1 - G43 (30 m length, 0.53 mm I. D., and 3 μm film thickness).

RESULTS AND DISCUSSION

Powder X-ray diffraction patterns

Figure 1 shows the XRD patterns of mesoporous alumina, 10BMN/MA, and 15BMN/MA. A single broad diffraction peak was observed at $2\theta = 1.5°$, confirming the mesoporous structure of meso-alumina (MA). By incorporating Co_3Mo_3N on mesoporous alumina, the broad peak at 1.5° became narrow owing to the blockage of mesoporous alumina pores by Co-Mo nitride.

Wide-angle XRD patterns of mesoporous alumina, 10BMN/MA, and 15BMN/MA are shown in Figure 2. Alumina was in γ-phase and the phase of Co_3Mo_3N is not detected in the supported catalysts. This is attributedtothe dispersion of the Co-Mo nitride phase on mesoporous alumina.

© STM Journals 2026. All Rights Reserved

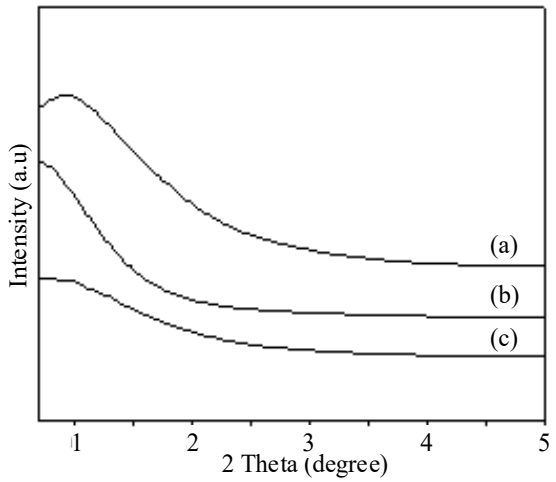


Figure 1. Low-angle XRD patterns of (a) Mesoporous alumina, (b) 10BMN/MA and, (c) 15BMN/MA catalysts.

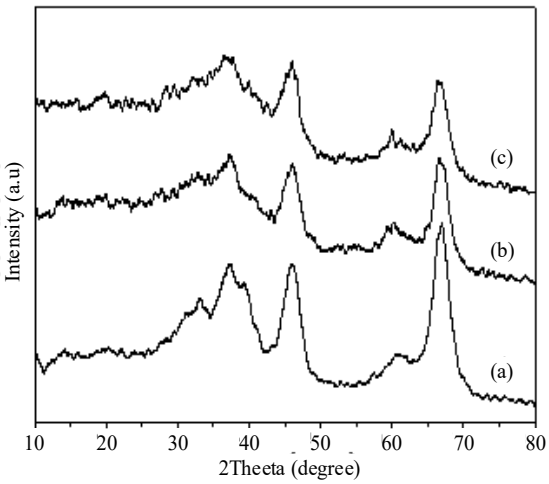


Figure 2. Wide-angle XRD patterns of (a) mesoporous alumina, (b) 10BMN/ MA and (c)15BMN/MA catalysts.

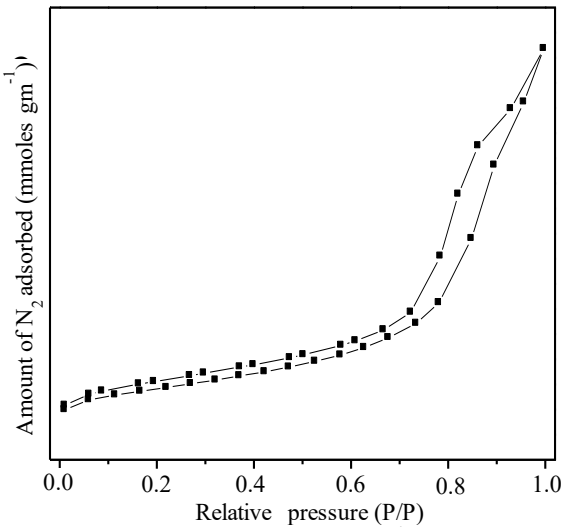


Figure 3. N_2 adsorption-desorption isotherms of mesoporous alumina (MA)

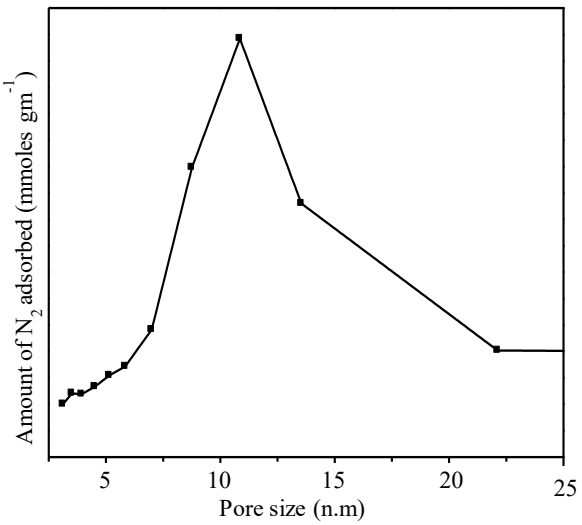


Figure 4. Pore size distribution of Mesoporous alumina

BET Surface Area Analysis

The N_2 adsorption–desorption isotherms of MA exhibited a type IV isotherm with a hysteresis loop and a surface area of 332 m^2 gm^{-1}, as shown in Figures 3 and 4 shows the pore size distribution of MA with a pore size of 10.85 nm and a pore volume of 1.18 cm^3 gm^{-1}. The surface areas of 10 and 15BMN/MA are 263 and 235.8 m^2 gm^{-1}

TPR Analysis

Figure 5 shows the TPR patterns of the BMN, 10 BMN, and 15 BMN catalysts. In the unsupported catalyst, T_{max} signals were observed at 800 and 1200 K, respectively, and the supported catalysts showed a shift in Tmax owing to the good dispersion of BMN on mesoporous alumina. The rate of H_2 consumption was high for the BMN, 15BMN/MA, and 10BMN/MA catalysts.

Activity Studies

From the activity data, it was observed that 10BMN/MA showed 1st an EB conversion of 82.1% and in 10th h conversion is 76%, with only a 6% decrease in the EB conversion. In the case of 15BMN/MA,

© STM Journals 2026. All Rights Reserved

in the presence of CO_2 – N_2 flow, the EB conversion (75.4%) was lower than that of 10BMN/MA (82.1%). The activity data for both catalysts are shown in Figure 6.

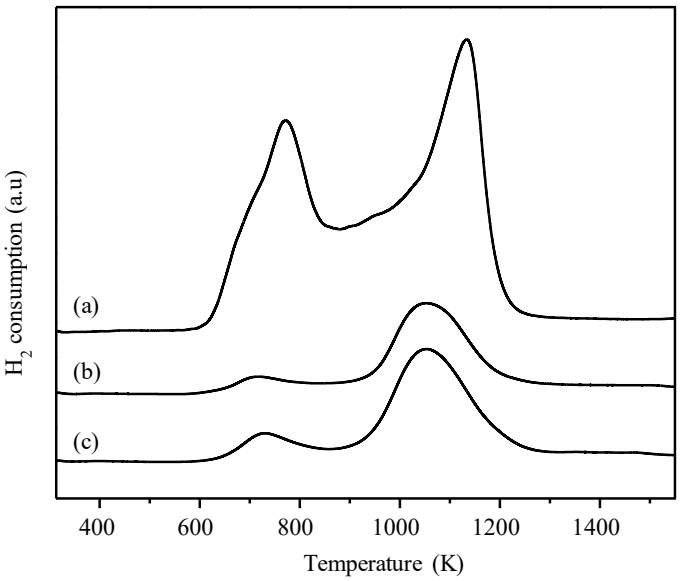


Figure 5. TPR patterns of (a) BMN, (b) 10BMN/MA and (c) 15BMN/MA catalysts.

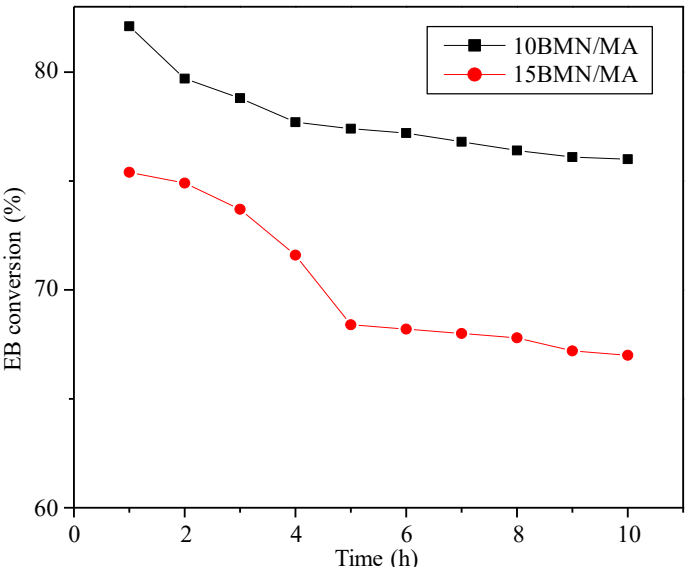


Figure 6. Activity data of 10BMN/MA and 15BMN/MA catalysts

CONCLUSIONS

The 10BMN/MA supported meso-alumina catalyst showed greater conversion and stable activity for up to 10h in a fixed bed reactor in the presence of CO_2 –N_2 flow. This is due to the high surface area and greater dispersion of the active phase (Co-Mo nitride) on meso-alumina in the case of the 10wt% BMN/MA catalyst compared to the 15BMN/MA catalyst. In the case of 15BMN/MA, with an increase in the quantity of the active phase (Co-Mo nitride), the dehydrogenation of EB decreased due to the sintering agglomeration of particles at higher temperatures.

REFERENCES

1. Addiego WP, Liu W, Boger T. Iron oxide-based honeycomb catalysts for the dehydrogenation of ethylbenzene to styrene. Catalysis Today. 2001 Sep 15;69(1-4):25-31.

© STM Journals 2026. All Rights Reserved

2. Mimura N, Takahara I, Saito M, Hattori T, Ohkuma K, Ando M. Dehydrogenation of ethylbenzene over iron oxide-based catalyst in the presence of carbon dioxide. Catalysis Today. 1998 Oct 19;45(1-4):61-4.
3. Kolios G, Eigenberger G. Styrene synthesis in a reverse-flow reactor. Chemical engineering science. 1999 Jul 1;54(13-14):2637-46.
4. Atanda L, Al-Yassir N, Al-Khattaf S. Kinetic modeling of ethylbenzene dehydrogenation over hydrotalcite catalysts. Chemical engineering journal. 2011 Jul 15;171(3):1387-98.
5. Balasamy RJ, Khurshid A, Al-Ali AA, Atanda LA, Sagata K, Asamoto M, Yahiro H, Nomura K, Sano T, Takehira K, Al-Khattaf SS. Ethylbenzene dehydrogenation over binary FeOx–MeOy/Mg (Al) O catalysts derived from hydrotalcites. Applied Catalysis A: General. 2010 Dec 20;390(1-2):225-34.
6. Liu BS, Rui G, Chang RZ, Au CT. Dehydrogenation of ethylbenzene to styrene over LaVOx/SBA-15 catalysts in the presence of carbon dioxide. Applied Catalysis A: General. 2008 Feb 1;335(1):88-94.
7. Nesterenko NS, Ponomoreva OA, Yuschenko VV, Ivanova II, Testa F, Di Renzo F, Fajula F. Dehydrogenation of ethylbenzene and isobutane over Ga-and Fe-containing mesoporous silicas. Applied Catalysis A: General. 2003 Nov 20;254(2):261-72.
8. Al-Yassir N, Le Van Mao R. Thermal stability of alumina aerogel doped with yttrium oxide, used as a catalyst support for the thermocatalytic cracking (TCC) process: an investigation of its textural and structural properties. Applied Catalysis A: General. 2007 Feb 7;317(2):275-83.
9. Niesz K, Yang P, Somorjai GA. Sol-gel synthesis of ordered mesoporous alumina. Chemical communications. 2005 Apr 13;41(15):1986-7.
10. Morris SM, Fulvio PF, Jaroniec M. Ordered mesoporous alumina-supported metal oxides. Journal of the American Chemical Society. 2008 Nov 12;130(45):15210-6.
11. Zhang K, Fu Z, Nakayama T, Suzuki T, Suematsu H, Niihara K. One-pot synthesis of hierarchically macro/mesoporous Al2O3 monoliths from a facile sol–gel process. Materials Research Bulletin. 2011 Nov 1;46(11):2155-62.
12. Wang H, Li W, Zhang M. New approach to the synthesis of bulk and supported bimetallic molybdenum nitrides. Chemistry of materials. 2005 Jun 14;17(12):3262-7.
13. Madhavi J, Suresh M, Babu GR, Prasad PS, Raju BD, Rao KR. N2 as a co-soft oxidant along with CO2 in ethylbenzene dehydrogenation to styrene over γ-Al2O3 supported Co–Mo nitride catalysts. Journal of CO2 Utilization. 2014 Dec 1;8:21-6.

© STM Journals 2026. All Rights Reserved