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Cerium ion-exchanged layered MCM-22: preparation, characterization and its application for esterification of fatty acids

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Abstract A series of cerium ion-exchanged MCM-22 catalysts was prepared by post-synthetic ion-exchange route. The resultant cerium-exchanged MCM-22 zeolite was systematically characterized using FTIR, powder X-ray diffraction (XRD), N_2 adsorption and desorption analysis, scanning electron microscopy, thermogravimetric analysis and diffuse reflectance UV–Vis spectral studies. The XRD pattern and FTIR data confirmed the MCM-22 structure. The diffuse reflectance UV–Vis spectroscopy showed coordination nature of the cerium ions. The cerium exchange MCM-22 zeolite showed promising activity for the esterification of fatty acids, achieving a maximum conversion of 75% at 70 °C in 24 h. Importantly the catalytic activity increases upon recycle due to hydrophic nature of recycled catalyst.

Keywords Zeolites · MCM-22 · Esterification of fatty acid · Cerium ions · Ion-exchange

1 Introduction

Heterogeneous catalysts are important tools in the fine chemical and pharmaceutical manufacture and in petroleum refining. In particular, aluminosilicate-based catalysts are extensively used due to their high stability, the flexibility of tuning of the active sites, and excellent activity. In particular, zeolites and zeolite-like molecular sieves are recognized as potential catalysts for petroleum and petrochemical processes [1–3].

MCM-22 is a recently developed silica-rich zeolite, first synthesized in 1990 by Mobil researchers, that exhibits high thermal stability and a large surface area [4]. The framework topology of this layered zeolite includes two independent pore systems—two-dimensional sinusoidal 10-membered ring (10-MR) apertures (4 Å × 5.9 Å) and 12-MR large supercages (7.1 Å × 7.1 Å × 18.2 Å). This unique ordered porous structure shows potential for ion-exchange capacity [5]. These supercages, stacked one above the other through double six-membered rings, cause interesting behaviors in catalytic applications. The MCM-22 zeolite crystallizes in the form of a precursor that contains a system comprising large external cages with 12 members, deemed "cups" (0.71 nm × 0.70 nm), along with 10-membered sinusoidal channels [6, 7]. The unique structure of MCM-22 facilitates its application in many catalytic hydrocarbon transformation processes, such as isomerization, alkylation, aromatization and cracking [8–12].

In this regard, it is worth mentioning that rare earth containing zeolites possessing multi-functionality, such as redox and acid-base properties, have been explored for several organic transformations, such as in the dehydration of alcohol, the alkylation of aromatic compounds, aldolization of ketones, and in the conduction of redox reactions [13, 14]. For example, cerium-containing zeolites facilitate the reduction in coke formation, as well as retaining their activity for longer durations in biomass conversion and FCC [15–17]. In addition, cerium-containing zeolites have been used as bifunctional catalysts for hydroisomerization, and have potential applications in corrosive protective coatings [18–21].

It is important to note that the increasing problem of petroleum demand due to the consumption of large amounts

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