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Insights into the Acidic and Basic Characteristics of modified Y- Zeolite in a Coupling Reactions

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Abstract:

Various Coupling reactions have been studied by using modified Y-Zeolite (Mg, Ca, Cu, Ni, etc.) heterogeneous catalysts. The structural, morphological and textural properties of catalysts were inspected by various physico-chemical procedures, for example ICP-OES, XRD, CO_2-TPD, NH_3-TPD, H_2-TPR, N_2sorption, Electron Microscopy (SEM, FE-SEM, TEM and HR-TEM), XPS, Raman Spectroscopy, FT-IR spectroscopy, NMR Spectroscopy, CHNS elemental analysis, etc. The study suggested that acidic as well as basic attributes of catalysts in addition to their strength (weak, moderate, moderately-strong, strong) have a vital role in coupling reaction performance and product selectivities . These modified Y-zeolite catalysts were explored for various organic coupling reactions to attain valuable desired products. The used catalysts were further analyzed by different techniques to understand insights into the materials stability and recyclability. Specifically, more attention is given to the acidity, basicity, and pore structure of the modified catalyst. And also, emphasis is placed on the acid-base properties of the catalyst for control of selectivity, rate of conversion and stability.

1. Introduction

Zeolites play important role in various types of heterogeneous catalytic conversion processes because of their characteristic topology, thermal stability, adsorption capacity, pore size, etc. NaY zeolite is composed of elements with high percentage of carbon, oxygen, aluminum and silicon and with trace amounts of calcium and sodium. It is commonly used as a good catalyst in petroleum industry. Zeolites with acidic and basic properties can be prepared by modification of NaY-Zeolite by alkaline earth and transition metals. By comparing catalyst acidic and basic characteristics, basic zeolites have so far gained little importance in industrial catalysis. The goal of our research is to prepare different heterogeneous catalysts using NaY Zeolite by utilizing various metals like Mg, Ca, Ni, Cu, etc. All the modified NaY Zeolites having acidity, basicity, pore structure, and metal ion location will be scrutinized for catalysis.

2. Experimental Section

2.1 Preparation of catalysts

Synthesis of alkaline earth metal exchanged NaY. About 2 g of NaY was dispersed in 40 mL of 1 M $MgNO_3$ solution in a 100 mL round bottom flask under continuous stirring and allowed to heat at 80 ^{O}C for 3 h. The resulting suspension was cooled to room temperature, followed by filtration, washed with deionized water and dried at 100 ^{O}C for 12 h. The material was further subjected to calcination at 300 ^{O}C for 4 h to obtain Mg exchanged NaY Zeolite. The above outlined procedure was also adopted for the synthesis of Ca exchanged NaY Zeolite.

Synthesis of Transition metal exchanged NaY catalysts. About 2 g of NaY was dispersed in 40 mL of 1 M Copper Nitrate solution in a 100 mL round bottom flask under continuous stirring and allowed to heat at 80^{O}C for 3 h. The resulting suspension was cooled to room temperature, followed by filtration, washed with deionized water and dried at 100 ^{O}C for 12 h. The material was further subjected to calcination at 300 ^{O}C for 4 h to obtain Cu exchanged NaY Zeolite. The above outlined procedure was also adopted for the synthesis of Ni exchanged NaY.

3. Results and discussion

3.1. Catalyst characterization

3.1.1. X-ray diffraction (XRD). The powder-XRD pattern of the modified NaY zeolite and parent NaY zeolite clearly confirmed the crystalline nature of the pure Y-type zeolite with no impurities (Figure 1). However, the diffraction intensity of the NaY zeolite partly decreased after metal exchange, but the similarity in the diffraction pattern indicates that the NaY zeolite retained its crystalline structure after metal exchange. No characteristic diffraction peaks pertaining to Mg, Ca, Ni and Cu metal were observed, pointing to well dispersed metal nanoparticles on the NaY zeolite support. The XRD results confirmed that the Mg, Ca, Ni and Cu metal nanoparticles were well decorated into the zeolite framework structure.

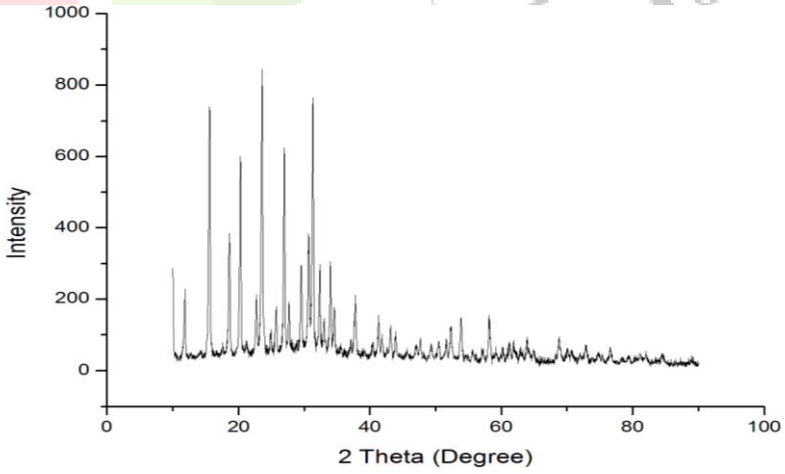

Figure 1. XRD Spectra of NaY Zeolite

3.1.2. FT-IR Spectroscopy

The absorption peak that appeared at 995–1180 cm^{-1}can be correlated with Si–O–Si linkage of the NaY zeolite framework. In addition to this, the sharp absorption peak that appeared in the frequency range of 3390–3696 $cm^{-1}$was due to the isolated surface hydroxyl (O–H) group present on the support.

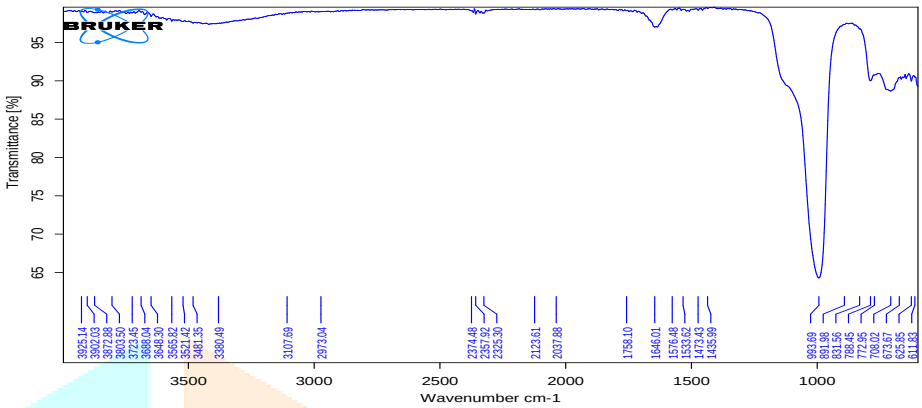

Figure 2. FT-IR Spectra of NaY Zeolite.

4. Applications of Zeolite materials in catalytic processes

Zeolites are commonly used as catalysts for several important reactions involving organic molecules as well as inorganic compounds. The most important are catalytic reactions, cracking, isomerization and also hydrocarbon synthesis. Zeolites can promote a diverse range of catalytic reactions including acid-base and metal induced reactions.

5. Conclusions

Alkaline earth metal as well as transition metals (Mg, Ca, Cu and Ni) exchanged NaY catalysts synthesized via a simple ion exchanged method are found to be excellent catalysts. The Acidic and Basic characteristic of modified Y-zeolites along with its strength is a deciding factor in catalytic performance and product selectivity in coupling reactions.

Conflicts of interest

There are no conflicts to declare.

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