Zeolites Commercial Applications –A Review

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Abstract
Zeolites can be classified into two general categories: normal and manufactured zeolites. Normal zeolites are composed of volcanic and sedimentary rocks such as Chabazite, clinoptilolite, and mordenite.These are commonly used as catalysts in the petrochemical industry for fluid catalytic cracking and hydrocracking, among other processes.Small-space containment of molecules by zeolites results in modifications to both structure and reactivity. These are microporous, three-dimensional crystalline solids of aluminium silicate and are used in ion exchange for the purification of hard water to soft water. In aqueous medium, the hydrated cations in zeolite can readily exchange with the other cations. These applications can be seen in water softening devices and zeolites are used in soaps, detergents. it also used to remove radioactive ions from the polluted water. Zeolites are alumino silicates that belong to the "molecular sieve" family of microscopic porous solids.

Keywords— Zeolite, catalyst, Ion Membrane, applications.

I. INTRODUCTION

Zeolites are aluminosilicate and microporous minerals, mostly utilize as commercial adsorbents and catalysts. These are tetrahedral, 3-D, crystalline minerals of aluminosilicate earth metals and have a place with the acidic catalysts. Swedish mineralogist Axel Fredrik Cronsted examined a material which produced large amount of steam from water when rapidly heating and named it as Zeolite [Greek word]. [1, 2]. Zeolites also called as molecular sieves are crystalline materials formed mainly by SiO4 and AlO4 with well-defined channels and cavities of molecular dimensions. The empty area within the crystal allows zeolites to distinguish molecules based on their size or geometric shape.

The structure and chemical composition decides the nature and chemical behavior of zeolite catalysts. The importance of zeolites in S&T field has no model in the field of materials and catalysis in the last 50 years. Zeolite micropores are of molecular size, which gives them adsorption (Beta Zeolite and Y-Type Series Zeolite), catalytic (SBA-15, 16; MCM-41, 48; Al-MCM-41, FDU-12, ZSM-5, 11, 22, 35; SAPO-11, 34; TS-1, **SSZ-13** and KIT-6), and ion-exchange properties [3].

Nowadays, the potential achievements in zeolite catalyst research have been increasing and applied in various applications. Applications for zeolite in process enhancement, green chemistry, hybrid materials, medicine, uses in animal feed, applications based on optics and electricity, multifunctional textiles, and nanotechnology. Zeolites can be found in nature and are also widely generated industrially [4, 5]. The International Zeolite Association Structure Commission evaluates each novel zeolite structure.

Industrial zeolite produced synthetically. The typical procedure needs heating aqueous solutions of alumina and silica with sodium hydroxide. Equivalent reagents include sodium aluminate and sodium silicate [7]. Structure-directing agents (SDA) like 8quaternary ammonium cations [8] are another variant.

Synthetic zeolites are more advantageous than natural analogs. These are produced in a uniform, pure phase state. It is also produced various structures that don't available in nature. Since the primary raw materials for production of zeolites are silica and alumina, both are the most abundant mineral components on earth, and then potential supply of zeolites is virtually unlimited [9]. zeolites have been utilized in a wide range of industrial applications such as ion-exchange processes, adsorption/separation and also as catalysts in the processes of oil refining and fine chemical synthesis.

A catalyst is a substance that can be added to a reaction to increase the reaction rate without getting consumed in the process. Catalysts typically speed up a reaction by reducing the activation energy or changing the reaction mechanism. Enzymes are proteins that act as catalysts in biochemical reactions.

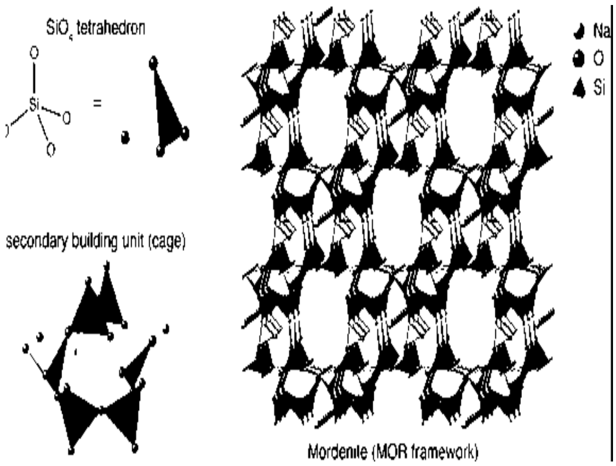

Fig 1: Microscopic structure of a zeolite (mordenite) framework [10]

Zeolites, which are crystalline microporous minerals, are frequently used in chemical and petrochemical production and in refining [11]. There has been a lot of discussion in the literature on the benefits of these substances as solid acid or basic catalysts. Because of their excellent catalytic behaviour, acid zeolites in particular have been used widely as catalysts in the refining and petrochemical industries. This is because they allow for the replacement of dangerous acids, the reduction of salts and other waste products, and the prevention of plant corrosion.

The quantity of research on the use of acidic zeolites as catalysts for the production of chemical intermediates and fine compounds has grown significantly during the past several years. Zeolite materials are good heterogeneous catalysts for making fine compounds because they have a variety of pore topologies and pore sizes, and their acidity (or basicity) can be controlled, and they can be regenerated.

II. PROPERTIES & OCCURRENCE

Zeolites have a porous structure with variety of cations: Na^+, K^+, Ca^{2+}, Mg^{2+} and others. These positive ions are rather loosely held and can readily be exchanged for others in a contact solution. The common mineral zeolites: stibnite, clinoptilolite, heulandite, natrolite, chabazite, phillipsite, and analcime. Zeolite's mineral formula, $Na_2Al_2Si_3O_{10}•2H_2O$, for natrolite, serves as an illustration. Cation exchanged zeolites possess different acidity and catalyze different reactions [11, 13]

The zeolites naturally form ash layers and volcanic rocks reacts with alkaline groundwater. Zeolites also crystallize in post-depositional environments over period of years in shallow marine basins. Zeolites that are found in nature are rarely pure and may contain small amounts of other metals, quartz, minerals, or other zeolites. As a result, many significant commercial applications that depend on uniformity and purity do not use naturally occurring zeolites.

III. LITERATURE SURVEY

The "molecular sieves" family of microporous solids, which includes zeolites, is composed mostly of silicon, aluminium, and oxygen. Zeolites have the general formula MxAlxSi1xO2yH2O, where M is either a metal ion or H+. The number of water molecules in the formula unit is denoted by y, while the value of x ranges from 0 to 1. Despite the broad variety of potential topologies, they are all created by joining the corner oxygen atoms of AlO48 and SiO48 tetrahedra to create covalent network architectures [12].

The term molecular sieve refers refers to a specific characteristic of these materials, namely the capacity to sort molecules in a selective manner largely using a size exclusion method. This is caused by a molecular-scale pore structure that is extremely regular. The size of the channels determines the largest molecular or ionic species that can fit through the pores of a zeolite. These are typically described by the size of the aperture's ring; for instance, the name "eight-ring" describes a closed-loop made up of eight silicon (or aluminium) atoms that are tetrahedrally coordinated and eight oxygen atoms. Due to a number of factors, such as strain brought on by the bonding between the units required to construct the overall structure or coordination of some of the rings' oxygen atoms to cations inside the structure, these rings are not always exactly symmetrical. As a result, many zeolites do not have cylindrical pores.

Ali et al. [12] compared synthetic gases and concluded that "LPG attracts applications due to its high heating value and clean combustibility."However, the conversion and selectivity of traditional catalysts are generally low.The hybrid system of methanol and zeolite-based catalyst was established as a potential approach to promote such a process. To strongly overcome the large demand of LPG and grasp the research work in this subject, The two main issues controlling the catalyst performance were the synergetic effect between the two hybridized catalysts and the used type of zeolite. The higher the zeolite member rings were thought to be, the better the LPG selectivity.

Gao et.al., [13] explained "efficient Na-FeMn/HZSM-5@Silicalite-1 catalyst was rationally designed for direct conversion of CO2 to aromatics. The tailor-made HZSM-5@Silicalite-1 core-shell zeolite was prepared by a facile solvent-free method. With the help of capsule-like zeolite-oriented synthesis, the solvent-free synthesis of core-shell zeolite could not only address pollution issues by eliminating the extensive use of organic reagents, but also demonstrate improved performance for separating para-Xylene (PX) from xylenes.The as-synthesized zeolite paves a new route for efficient conversion of CO2 molecules into valuable PX, and provides a facile method for regulating surface acid properties of zeolite."

Yogi et.al., [14] explained this work "to develop a sustainable Ni/Zeolite catalyst derived from geothermal solid waste for waste cooking oil processing. Results have shown the synthesized Ni/Zeolite catalyst was granular in shape and crystalline with increased surface area and pore volume. Meanwhile, at 3% Ni/Zeolite catalyst addition and 60 °C operating temperature, the highest biodiesel yield obtained was 89.4%.."

Isostearic acid, a C18 saturated branched chain fatty acid containing one or more methyl or ethyl groups on the carbon chain, is of great interest for the oleochemical industry due to its interesting physicochemical properties. As a byproduct of the dimerization of unsaturated fatty acids by acid clay, its current industrial manufacturing is inefficient. Therefore, zeolit-based novel catalytic systems are the main subject of research. Zeolites are preferable than acid clay catalysts in that they can produce noticeably greater quantities of branched fatty acids. Focus is on the reaction mechanisms taking place during reaction, the analysis of the reaction product and the zeolite catalysts themselves [15].

Yang et.al., [16] explained the challenges in the “elimination of NOx attracts much attention due to the negative effect on the environment, and the selective catalytic reduction of NOx with CH4 (CH4-SCR) was considered as an alternative technology to remove the NOx and CH4 simultaneously. Subsequently, a detailed review of the represent metal-exchanged zeolite catalysts in the CH4-SCR reaction, including Co-, In-, and other metal-exchanged zeolite catalysts with different structures.”

Gilar [17] reviewed on various applications and uses in real environment and the following figure shows some of the applications with natural zeolite.

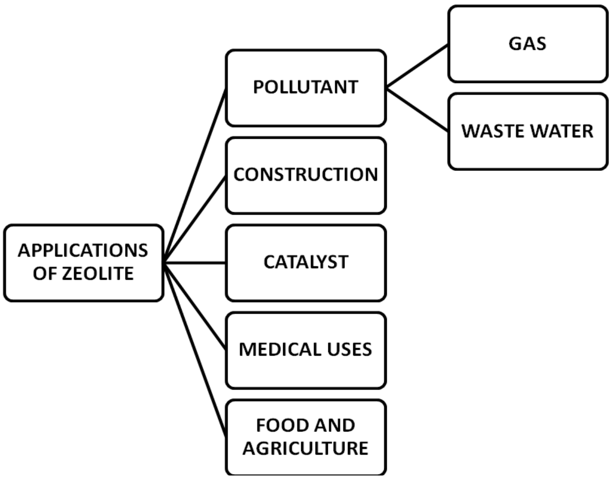

Fig 2: Applications of Zeolite[17]

IV. CONCLUSION

In this paper the authors reviewed on commercial applications with Zeolite catalyst. Zeolites advantages are: inexpensive and abundant. This paper addressed about natural and manufactured zeolites and their usages. The related applications are and authors work addressed in this paper.

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