

Characterization of ZHY and TCA/ZHY Catalysts for Hydration of α -Pinene

N. Wijayati, H. D. Pranowo, Jumina, Triyono, and G. K. Chuah

Abstract—The TCA/ZHY catalyst (Si/Al = 3.25) was prepared by impregnation of the Zeolite HY (Si/Al = 2.89) with amount of an aqueous solution of TCA. The physico-chemical properties were investigated by XRD, ^{29}Si and ^{27}Al MAS NMR, BET, SEM, NH_3 -TPD and FT-IR spectroscopy of pyridine adsorbed. The activity of catalytic of these catalysts has been carried out over the liquid-phase hydration of α -pinene to give α -terpineol as a major product and hydrocarbon as a minor products.

Index Terms—TCA/ZHY, α -pinene, α terpineol, hydration.

I. INTRODUCTION

H-Zeolites are natural or synthetic crystalline, microporous, aluminosilicate materials with structures consisting of three dimensional frameworks of SiO_4 and AlO_4 tetrahedra linked through oxygen bridges [1]. Zeolite Y is a highly versatile molecular sieve from the faujasite family of zeolites whose 7.4 Å, three-dimensional pore structure and solid acidity make it useful as ion exchange, adsorption, heterogeneous catalysis, biosorption supports, polymer catalytic degradation and also attract interest in materials science for the development of functional materials and in nanotechnology [2]-[5]

Zeolite is used as molecular sieve. Species with kinetic diameter which make them too large to pass through a zeolite pores are effectively sieved [6]. Strong electrostatic field within a zeolite cavity results in a very strong interaction with polar molecules such as water. Furthermore, non polar molecules are also strongly absorbed due to the polarizing power of this electric field. Thus, excellent separations can be achieved by zeolites even when no steric hindrance occurs. Therefore, adsorption based on molecular sieve, electrostatic fields and polarity ability accounts for the considerable economic values of zeolite in adsorptive application [1]-[5].

The hydration reaction of α -pinene in the presence of zeolite catalysts has been well studied, and intensely so in the last ten years. Vital and co-workers [7] reported the use of solid acid catalysts such as zeolites and impregnated phosphomolybdic acid (HPMo) on polymeric membranes for

α -pinene hydration, achieving 100% conversion with selectivities for α -terpineol between 50% and 70%, although it required 150 h of reaction time. Mochida et al. [8] reported the use of zeolites and obtained 100% conversion, but with low selectivity for alcohols (around 57%). The TCA/ $\text{ZrO}_2 \cdot n\text{H}_2\text{O}$ catalyst was active and selective for producing alcohols, with a conversion of 57% and a selectivity of 75% of total alcohols, and showed 57% selectivity for α -terpineol Avila et al. [9]

In this paper describes the characterization of the TCA/ZHY catalyst and the use in the hydration of α -pinene as catalysts for the formation of α -terpineol.

II. PROCEDURE

A. Experimental

The catalysts were characterized by X-Ray Diffractometer (D-Max III (Rigaku) dengan radiasi Cu K α ($\alpha = 1.5378 \text{ \AA}$, 40kV, 30mA). The NMR spectra were obtained at 9.4 T on a Bruker DRX-400 spectrometer using 4mm ZrO₂ rotors at room temperature. ^{29}Si MAS NMR spectra with high power proton decoupling were obtained at 79.49MHz with a spinning rate of 12 kHz, pulse length of 3 mikros and a recycle time of 20 s. 4 mm rotors were used and the ^{29}Si chemical shifts are reported relative to TMS. The ^{27}Al MAS NMR spectra were recorded at 104.26 MHz (9.4 T), with an excitation pulse of 1.7 mikros and a recycle delay of 5 s. The ^{27}Al chemical shifts were measured relative to aqueous Al (NO_3)₃. The morphology and mean crystallite size of the zeolites were determined by scanning electron microscopy (SEM) in a JEOL JFC-1600 and JSM-6701F equipment. 1) Pt auto fine coater, Model: JEOL JFC-1600; Parameters: 20mA, 30sec coating time; Pt thickness: approx. 5nm. 2) FESEM. Model: JEOL JSM-6701F Voltage range: 0.1 - 30kV, Magnification: 25X-650kX, Resolution: 1nm by specification. Physisorption of N_2 , BET analysis was carried out on a Quantachrome® ASiQwin™, Autosorb iQ Station adsorption analyzer. Prior to adsorption, the samples were outgassed at 300°C for 3 hours. NH_3 -TPD experiments were carried out on a conventional setup equipped with a thermal conductivity detector. TPD profiles were obtained in a temperature range from 100°C to 500°C at a constant heating rate of 10°C /min in a 13 cm³ /min flow of helium. The IR spectroscopy of pyridine adsorbed (Py-IR) was carried out on a (Hitachi 270-50; Perkin Elmer Paragon 1000 PC; Shimadzu FTIR-8201PC). GC-MS instrument (Agilent GC/MSD (7890A/5975C). The column used was DB-5MS 27m x 0.25mm x 0.25um B-5, Mass range: 41-500amu, Carrier gas flow rate: 1ml/min, Injector temperature: 260°C; Temperature program: 50°C (2min)-260°C(5min), heating

Manuscript received February 27, 2013; revised May 30, 2013.

N. Wijayati is with the Doctorate Program, Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Gadjah Mada, Yogyakarta

H. D. Pranowo is with the Department of Chemistry, State University of Semarang, J. Raya Sekaran Gunungpati Semarang 50229 (e-mail: nanik_unnes@yahoo.com).

Jumina and Triyono are with the Department of Chemistry, Universitas Gadjah Mada, Jl. Sekip Utara, Yogyakarta 55281.

G. K. Chuah is with the Department of Chemistry, National University of Singapore, 3 Science Drive3 Singapore 117543.

rate 5°C/min; Flow: 1 mL/min; split ratio: 20. Note: 3 μ L of sample TP diluted with 1 mL of methanol for GCMS analysis.

B. Catalytic Test

The reactions were carried out in a glass reactor equipped with magnetic stirrer, sampling port, temperature bath, and condenser. A mixture of 1.84 mmol of α -pinene, 2.5 mL of H₂O, and 3.4 mL of isopropyl alcohol was loaded into reactor. The mixture was stirred and warmed up to the desired temperature. Once the desired temperature was reached, the 400 mg of catalyst was added into the reactor. The reaction products were analyzed by GC by taking samples at 10, 20, 30, 60, 120, and 240 min after the addition of catalyst. The samples were taken at different interval of time to study the variation of reactant concentration and product. The samples were centrifuged at high speed of rotation (350 rpm) for about 10 min at ambient temperature to ensure that they were free of solid catalyst. Peak identification of the products were done by GC-MS analysis

III. RESULT AND DISCUSSION

A. XRD

The X-ray powder diffraction (XRD) patterns of the ZHY and TCA/ZHY with SiO₂/Al₂O₃ were shown in Fig. 1. The XRD patterns show that all the samples were zeolites topology, well crystallined and are free from impurities. Furthermore, the XRD patterns were used to calculate the average crystal size and the relative crystallinity of the different zeolites [1].

The relative crystallinity of the modified zeolites was calculated by comparing the average intensities of the most intense peaks with that of the parent zeolite, HY, assuming 100% of crystallinity for the starting material. The crystal size and relative crystallinity of the ZHY and TCA/ZHY.

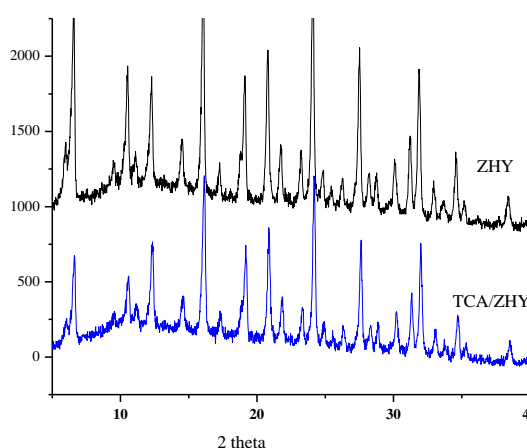


Fig. 1. XRD patterns of ZHY and TCA/ZHY catalysts

B. ²⁹Si MAS NMR

The ²⁹Si MAS NMR spectra of the ZHY and TCA/ZHY samples are shown in Fig. 2. It is well known that a ²⁹Si MAS NMR spectrum of the ZHY may contain up to five lines depending on the number of aluminum atoms and silanol groups connected to the silicon atom. The ²⁹Si MAS NMR

spectrum of the parent ZHY sample shows the presence of four components, corresponding to Si(0Al), Si(1Al), Si(2Al) and Si(3Al) species at -108, -102, -99, and -94 ppm, respectively, similar to that observed by Yan et al, [10]

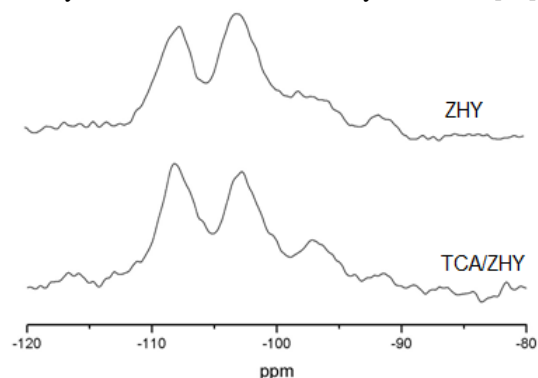


Fig. 2. ²⁹Si MAS NMR spectra of ZHY and TCA/ZHY

After impregnated by 35% trichloroacetic acid under reflux for 5 h, the intensities of these lines are nearly unchanged, which suggests that the framework structure is kept almost intact. However, with the concentration of the TCA solution, there is another line developed at -112 ppm, which is assigned to Si(4Si) of silica. At this stage, some of the framework Al species are removed from the lattice by TCA and a large part of the framework is ruined, as indicated by its corresponding XRD pattern (Fig. 1). Meanwhile, it is clear that other bands (those at -108 and -103 ppm) become broadened as compared with the parent ZHY, suggesting that impregnated TCA leads to a distortion of the coordination environment of the corresponding framework silicon atoms and, thus increases the chemical shift distribution. It is necessary to make an unambiguous assignment of the peaks at -94 and -102 ppm because, for example, in the case of ZHY, we can hardly attribute them solely to the Si(3Al) and Si(1Al) species, respectively. As can be seen, compared with Fig. 2, the relative ratio of the intensity of the line at -102 ppm to that at -108 ppm increased in the spectrum of the TCA/ZHY, suggesting that the line at -102 ppm may be partly due to the (OSi)₃SiOH species that contains a silanol group. Thus, the line at -102 ppm is in fact an overlap of Si(1Al) and (OSi)₃SiOH sites in the spectrum of parent ZHY. After the impregnated by the 35% TCA, the intensity of the line at -102 ppm is further increased with respect to that of the line at -108 ppm, and attains the maximum. This fact shows that TCA can remove lattice aluminum from the zeolite framework, thus resulting in the so-called silanol nests, which is confirmed by the following ²⁷Al MAS NMR spectra which show an increase in the intensity of the silanol groups at 1.7 ppm. The enhanced signals at -93 ppm illustrate the presence of the (SiO)₂Si(OH)₂, also due to Al removal. Moreover, the peak at -112 ppm corresponding to Si(4Si) of silica becomes more obvious.

C. ²⁷Al MAS NMR

The ²⁷Al MAS NMR has been widely used to follow the local Al environment as a function of the treatment. ²⁷Al MAS NMR spectra of ZHY show two components were detected centered at 0 and 60 ppm, corresponding to octahedrally and tetrahedrally-coordinated Al species, respectively, can be clearly distinguished [10]-[12]. At the

same time, for the TCA/ZHY samples, the peaks at around 60 and 0 ppm undergo different changes. As shown in Fig. 3, both the peaks at 60 and 0 ppm seem to become narrowed upon a TCA/ZHY. It is especially the case for the one at 0 ppm. Here, with impregnated 35% TCA, resulting in the narrowing of the band at 0 ppm and the intensity of the 60 ppm peak decreases. ^{27}Al MAS NMR signals at ca. 60 ppm (Al^{IV}) and the signals at ca. 0 ppm are due to octahedrally coordinated aluminum species (Al^{VI}) [13].

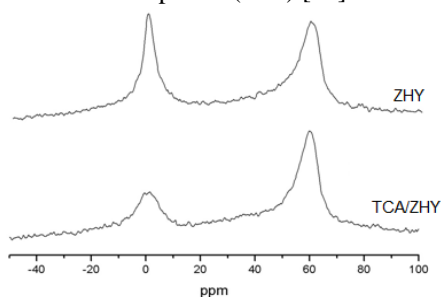


Fig. 3. ^{27}Al MAS NMR spectra of ZHY and TCA/ZHY

D. SEM

Scanning electron microscopy (SEM) concludes that the morphology of the outer surface of the zeolite crystals is virtually not affected by TCA treatment (Fig. 4).

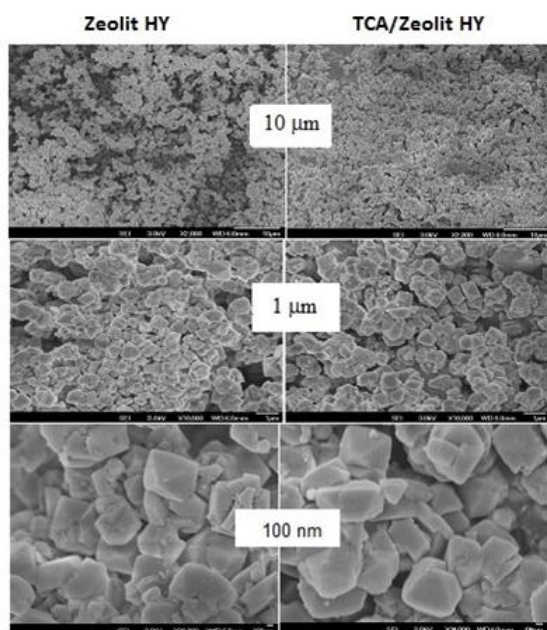


Fig. 4. SEM image of ZHY and TCA/ZHY in different magnifications

E. BET (N_2 Adsorption-Desorption)

Table II shows the textural properties of the ZHY and TCA/ZHY catalysts. The BET surfaces of the TCA/ZHY catalyst was lower than those of the ZHY, with an observed decrease of 13.54%. The pore diameter (D_p) volumes of the TCA/ZHY catalyst was also lower than ZHY, decreased (29.43%) with respect to that of the ZHY. In the case, the pore volume of TCA/ZHY was higher than ZHY, with an observed increase of 12.12%. This increase is difficult to justify, and this small difference can be attributed to the low precision of the BJH method in the micropore region. The adsorption isotherms for the ZHY and TCA/ZHY are of type IV according to IUPAC classification. The average pore

diameters of ZHY was slightly larger than 2 nm, the upper limit established by the IUPAC for mesopores (2-50 nm) [13]. In this type of isotherm for TCA/ZHY, the adsorption takes place at relatively low pressures and was characteristic of microporous solids, the average pore diameter was lower than 2 nm.

TABLE II: TEXTURAL PROPERTIES OF THE CATALYSTS DETERMINED OF BET

Sample	SBET (m ² /g)	V _p (cm ³ /g)	D _p (Å) BJH method
ZHY	619	0.087	27.05
TCA/ZHY	530	0.099	19.09

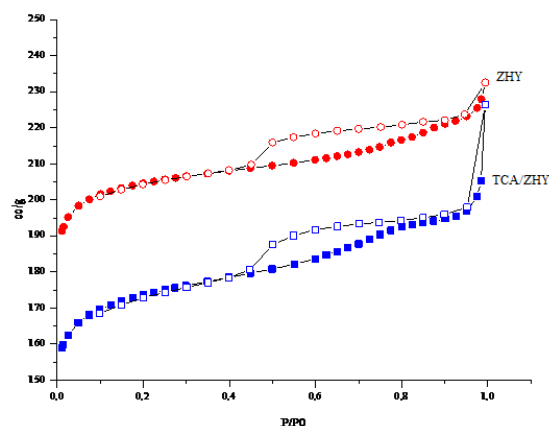


Fig. 5. N_2 adsorption-desorption isotherms at 77 K for ZHY and TCA/ZHY

This is indicated that samples of ZHY have larger surface area and pore volume than the TCA/ZHY, due to the larger number of tetrahedral silicon and aluminum species in zeolite skeleton in the former and the more complete pore structure formed.

F. Acidity

The acidity of the ZHY and TCA/ZHY catalysts were characterized by the NH_3 -TPD and Py-IR. Temperature-programmed desorption (TPD) of ammonia often has been used to characterize the acidity of zeolites. First, desorbed ammonia peaks must be identified, because low-temperature desorption contains considerable amounts of ammonia physically adsorbed on NH_4^+ cations. Therefore, counting a low-temperature peak as an acid site mistakenly leads to overestimation of the number of acid sites. When the TPD is measured under normal conditions, it is controlled by the free readsorption of ammonia, and thus the temperature for ammonia desorption does not simply correlate with the strength of acid sites [14].

NH_3 -TPD was carried out to compare the acid strength and amount of the samples (Table III), and all samples had two NH_3 desorption peaks, which indicated that weak and strong acid sites were present in these samples (Fig. 6). For the TCA/ZHY catalyst, the amount of total acid sites decreased, and the strength of strong acid sites increased with the increasing of $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio.

The amount of Brønsted and Lewis acid sites of the studied samples, as determined by pyridine adsorption (FT-IR), are shown in Fig. 7. Py-IR spectra of two characteristic absorption peaks, of which 1543 cm^{-1} and 1442 cm^{-1} , attributable to pyridine adsorbed on Brønsted acid and Lewis acid sites, respectively [15]-[17].

The amount of Brönsted acid sites provided by hydroxyl bridge skeleton decreased with the increasing of the $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio. Compared to TCA/ZHY pattern, the ZHY samples provided more Brönsted acid sites, which indicates more aluminum species enter into the framework. However, this results in accordance with the changes of strong acid sites detected by NH_3 -TPD. It is thus clear that impregnation TCA to the ZHY can not only change the amount of acid sites, but also effectively change the distribution of acid sites.

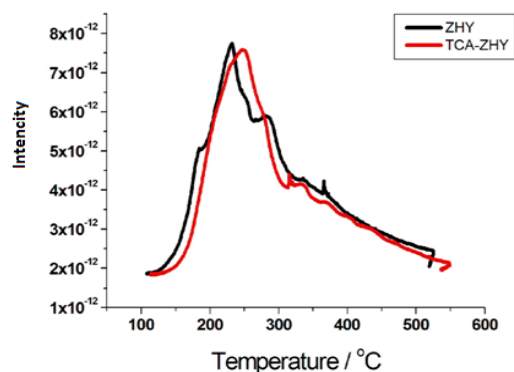


Fig. 6. NH_3 -TPD ZHY and TCA/ZHY catalysts

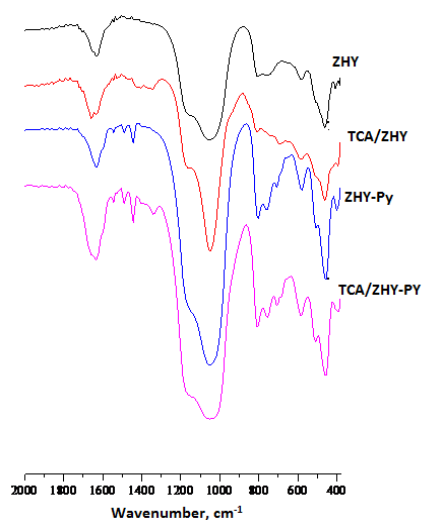


Fig. 7. FT-IR spectra of ZHY and TCA/ZHY

G. Catalytic Activity

Catalytic study were performed using ZHY and TCA/ZHY. The molecular size of α -pinene was estimated to be $0.62 \times 0.59 \times 0.53$ nm, which is smaller than ZHY and TCA/ZHY catalysts [8]. The reaction was carried out in an excess of water with α -pinene as the limiting reagent. α -Pinene was almost immiscible in water at the reaction conditions. It forms a separated organic phase in the reactor. The reaction taken place over the catalyst surrounded by the aqueous phase. α -Pinene should adsorb on acid site to promote the acid catalyzed reaction the presence of water. The reaction product, i.e. α -terpineol, was non polar compounds and was extracted out into the organic phase simultaneously during of the reaction thereby giving significant conversion.

Effect of reaction time on the α -pinene conversion and selectivity of terpineol for ZHY and TCA/ZHY catalysts were shown in Fig. 8.

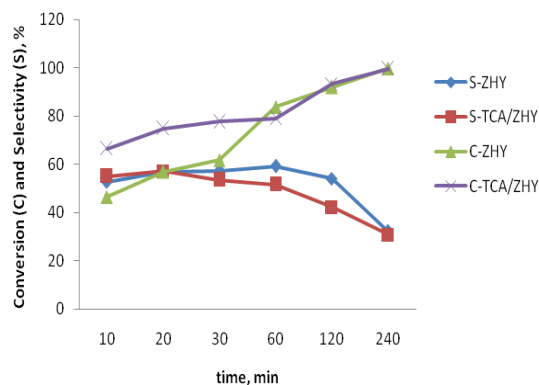


Fig. 8. Conversion and selectivity of α -terpineol vs. reaction time. Reaction conditions: 1.84mmol α -pinene, 2.5mL H_2O , 3.4mL $(\text{CH}_3)_2\text{CHOH}$, 400 mg catalyst, temperature 65°C ; S= Selectivity; C= Conversion

To achieve a well mixing between the reagents and the α -pinene during reaction, they must be stirred well at constant rate. The observed conversion of α -pinene with TCA/ZHY was 1.43 times higher with respect to that observed with ZHY at from 10 min until 30 min, after that, the conversion with TCA/ZHY the same as ZHY until 120 min. The hydration reaction with TCA/ZHY, the highest selectivity of α -terpineol was 57.14% with a conversion of 73.80% at 20 min, whereas the higher conversion was 99.63% with selectivity of 30.79% at 120 min.

Fig. 4 show that the main products were α -terpineol, camphene, terpinolene, and limonene. Castanheiro, *et al.* [18] proposed reaction scheme for the acid catalyzed hydration of α - and β -pinene. They used molybdophosphoric acid as catalyst and obtained limonene, γ -terpinolene, and α -terpineol as main products.

The acid catalyzed the hydration reaction of alkenes in aqueous solution. The acid transfers a proton to double bond of the alkene forming an intermediate of carbocation. The carbocation can lose a proton and generate monocyclic and bicyclic hydrocarbons or, in the presence of a nucleophile, give to monocyclic alcohol. In the hydration of terpenes, variation products might be obtained depending on the catalyst and reaction conditions [8]-[9], [19], [20]

The catalyst of TCA/ZHY was studied for this hydration reaction. The internal surface of catalysts being highly hydrophobic possesses affinity towards non polar molecules like that of α -pinene [7]-[9]. Y-Zeolite showed high activity for α -pinene hydration, indicating the high potential of this catalyst as an alternative solid acid catalyst to conventional homogeneous catalyst. By Evaluating this work, was a good candidate for the industrial hydration of α -pinene, due to its easy separation from reaction products and low cost.

IV. CONCLUSION

XRD and SEM shows that the TCA/ZHY nanocrystals obtained are highly crystalline, and its pore volume is moderate Fig and its pore diameter 18.09 \AA prove that it is a nanoporous material. ^{29}Si MAS NMR shows that TCA can remove lattice aluminum from the zeolite framework, thus resulting in the so-called silanol nests, which is confirmed by the following ^{27}Al MAS NMR spectra. The Si/Al ratio of ZHY and TCA/ZHY were 2.89 and 3.25, respectively. The TCA/ZHY nanocrystals show high N_2 adsorption; and BET

surface area and pore volume are determined to be $530 \text{ m}^2 \text{ g}^{-1}$ and $0.099 \text{ cm}^3 \text{ g}^{-1}$ respectively. NH_3 -TPD spectra show that impregnation TCA to the ZHY can not only change the amount of acid sites, but also effectively change the distribution of acid sites.

The TCA/ZHY was a good candidate for the industrial hydration of α -pinene, due to its easy separation from reaction products and low cost. The hydration of α -pinene catalyzed by TCA/ZHY was fast and leads mainly to monocyclic terpenes and alcohols with α -terpineol as the principal product (up to 57%).

ACKNOWLEDGMENT

The authors would like to thank Directorate General of Higher Education (DGHE), Department of National Education Republic Indonesia for to support. The authors thank to, Department of Chemistry, Faculty of Science, National University of Singapore (NUS) for assistance with sample characterization

REFERENCES

- [1] B. Silva, H. Figueiredo, O. S. G. P. Soares, M. F. R. Pereira, J. L. Figueiredo, A. E. Lewandowska, M. A. Bañares, I. C. Neves, and T. Tavares, "Evaluation of ion exchange-modified Y and ZSM5 zeolites in Cr(VI) biosorption and catalytic oxidation of ethyl acetate," *Appl. Catal. B- Environ.*, vol. 117-118, pp. 406-413, 2012.
- [2] H. Su, H. S. Kim, S. M. Seo, S. O. Ko, J. M. Suh, G. H. Kim, and W. T. Lim, "Location of Na⁺ Ions in Fully Dehydrated Na⁺-saturated Zeolite Y (FAU, Si/Al = 1.56)," *Bull. Korean Chem. Soc.*, vol. 33, no. 8, pp. 27-85, 2012.
- [3] C. K. Modi and P. M. Trivedi, "Synthesis, characterization and catalytic behaviour of entrapped transition metal complexes into the zeolite Y," *Adv. Mat. Lett.*, vol. 3, no. 2, pp. 149-153, 2012.
- [4] C. J. A. Mota and N. Rosenbach, "Carbocations on Zeolites. Quo Vadis?" *J. Braz. Chem. Soc.*, vol. 22, no. 7, pp. 1197-1205, 2011.
- [5] Y. Zheng, X. Li, and P. K. Dutta, "Exploitation of Unique Properties of Zeolites in the Development of Gas Sensors," *Sensors*, vol. 12, pp. 5170-5194, 2012.
- [6] M. M. Rahman, M. B. Awang, and A. M. Yusof, "Preparation, Characterization and Application of Zeolite-Y (Na-Y) for Water Filtration," *Aust. J. Basic and Appl. Sci.*, vol. 6, no. 1, pp. 50-54, 2012.
- [7] J. Vital, A. M. Ramos, I. F. Silva, H. Valente, and J. E. Castanheiro, "The effect of α -terpineol on the hydration of α -pinene over zeolites dispersed in polymeric membranes," *Catal. Today*, vol. 67, pp. 217-223, 2001.
- [8] T. Mochida, O. Ryuichiro, H. Naoto, K. Yuichi, and O. Toshio, "Hydration of α -pinene over hydrophobic zeolites in 1,4-dioxane-water and in water," *Micropor. Mesopor. Mat.*, vol. 101, pp. 176-183, 2007
- [9] M. C. Avila, N. A. Cornelli, E. R. Castellon, and A. J. Lopez, "Study of solid acid catalysis for the hydration of α -pinene," *J. Mol. Catal. A-Chem.*, vol. 322, no. 1-2, pp. 106-112, 2010.
- [10] Z. Yan, M. Ding, Z. Jianqin, L. Xianchun, L. Xiumei, H. Xiuwen, B. Xinhe, C. Fuxiang, X. Lei, and L. Zhongmin, "On the acid-dealumination of USY zeolite: a solid state NMR investigation," *J. Mol. Catal. A: Chem.*, vol. 194, pp. 153-167, 2003.
- [11] J. Jiao, W. Wang, B. Sulikowski, J. Weitkamp, and M. Hunger, "²⁹Si and ²⁷Al MAS NMR characterization of non-hydrated zeolites Y upon adsorption of ammonia," *Micropor. Mesopor. Mat.*, vol. 90, pp. 246-250, 2006.
- [12] S. N. Azizi and S. E. Tilami, "Theoretical and Experimental ²⁷Al NMR Chemical Shift Studies on End-Group Aluminates Linked to Different Silicate Species," *J. Chin. Chem. Soc-Taipei*, vol. 56, pp. 898-907, 2009.
- [13] B. Li, D. Xu, Z. Jiang, X. Zhang, W. Liu, and X. Dong, "Pervaporation performance of PDMS-Ni²⁺Y zeolite hybrid membranes in the desulfurization of gasoline," *J. Membrane Sci.*, vol. 322, pp. 293-301, 2008
- [14] L. Liu, L. Zhao, and H. Sun, "Simulation of NH₃ Temperature-Programmed Desorption Curves Using an ab Initio Force Field," *J. Phys. Chem. C.*, vol. 113, pp. 16051-16057, 2009
- [15] K. Suzuki, T. Noda, N. Katada, and M. Niwa, "IRMS-TPD of ammonia: Direct and individual measurement of Brønsted acidity in zeolites and its relationship with the catalytic cracking activity," *J. Catal.*, vol. 250, pp. 151-160, 2007.
- [16] C. K. Modi and P. M. Trivedi, "Synthesis, characterization and catalytic behaviour of entrapped transition metal complexes into the zeolite Y," *Adv. Mat. Lett.*, vol. 3, no. 2, pp. 149-153, 2012
- [17] B. A. Holmberg, H. Wang, and Y. Yan, "High silica zeolite Y nanocrystals by dealumination and direct synthesis," *Microporor. Mesopor. Mat.*, vol. 74, pp. 189-198, 2004
- [18] J. E. Castanheiro, I. M. Foseseca, A. M. Ramos, R. Oliveira, and J. Vital, "Hydration of α -pinene over molybdophosphoric acid immobilized in hydrophobically modified PVA membranes," *Catal. Today*, vol. 104, pp. 296-304, 2005.
- [19] P. A. R. Dutenhefner, A. Kelly, M. D. Silva, H. S. Rafiq, I. V. Kozhevnikov, and V. G. Elena, "Hydration and acetoxylation of monoterpenes catalyzed by heteropoly acid," *J. Mol. Catal. A-Chem.*, vol. 175, no. 1-2, pp. 33-42, 2001
- [20] H. Pakdel, S. Sharron, and C. D. Roy, " α -Terpineol from Hydration of Crude Sulfate Turpentine Oil," *J. Agric. Food. Chem.*, vol. 49, no. 9, pp. 4337-4341, 2001.



N. Wijayati was born in Blora, Central Java (Indonesia) in 23rd October, 1969. She received his master's degree in Organic Chemistry from the Universitas Gadjah Mada, Indonesia. At present, he is doing Ph.D. in Department of Chemistry, FMIPA, Universitas Gadjah Mada under the supervision of Prof. Dr. Harno D.P., Prof. Dr. Jumina, and Prof. Dr. Triyono. Her area of interest is organic reaction using homogeneous and heterogeneous catalysts.