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Conversion of CO_2 to Methane (CH_4) using Ni-Al Based Catalyst and Mg as Promoter via Methanation Process

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ABSTRACT

The increase of CO_2 gas in the atmosphere, which can cause climate change, is one of the reasons for converting it into value-added chemicals and renewable fuels. One way to reduce CO_2 in the atmosphere is to capture and store CO_2. The conversion of CO_2 into chemical fuels can be a method to reduce the problem of global warming and provide alternative chemical fuels.The purpose of this research is to obtain methane gas through the CO_2 methanation process. Methane gas is produced using nickel-alumina based catalyst and Mg as promoter. The CO_2 methanation process is carried out in a 500ml Erlenymeyer flask with CO_2 gas flowing from the CO_2 tube as the raw material in the process. In this research, the amount of catalyst is adjusted by varying the ratio of Nickel-Alumina catalyst 1:1, 1:2, and 1:3, 2:1, 3:1. Analysis of the methane content was used a Multi Gas Detector Analyzer and for catalyst used X-Ray Diffractionmeter. It is obtained from the research result that the most optimum variation of the Nickel-Alumina catalyst ratio is at the ratio of 3:1. The CO_2 conversion to CH_4 from the methanation process by using 3:1 Nickel-Alumina ratio also has a significant percentage of 1.82% for the methane content and 0.2% for the CO_2 content.

Keywords: *CO_2 conversion, Methanation, Nickel, Alumina, Gas Analyzer*

1. INTRODUCTION

Climate change, natural destruction and environmental degadation have attracted serious attention from society, government and corporations. For the world community, it turns out that the many visible signs of global warming have increased their awareness of the destruction of nature [1]. As a result, the phenomenon of climate change has increased concern about the risks that the world community will have as a result of climate change. The two main things that cause the phenomenon of climate change and natural damage are pollution caused by solid waste and pollution caused by emissions of carbon dioxide gas (CO_2) or known as geenhouse gases [2].

One of the best approaches is to capture and convert CO_2 carbon dioxide into green fuels like methane. On the other hand, a sustainable way to solve the energy problem is to produce alternative energy sources, however, challenges related to renewable energy storage prevent the development of such technology. CO_2 conversion to methane using renewable hydrogen has geat potential and could provide a solution to both the problems of excessive CO_2 levels, and a temporal mismatch between renewable energy production and demand for electricity and hydrogen storage. The CO_2 methanation process requires a metal-based catalyst. Hydrogenation of CO_2 is also achieved by metal/metal hybrid oxides and metal hydrides. CO_2 polymerization though was reported by metal free catalysts. The critical challenge for the reported metal catalysts is poor stability due to oxidation and/or sintering of the active sites (metal nanoparticles), because methanation is a high temperature reaction [3].

Several attempts have been made to stabilize them but due to the high surface energy of metal nanoparticles, they tend to oxidize or sinter/agglomerate on exposure to heat and/or air [4]. Thus, there is an urgent need to discover and develop heterogenity of highly active, selective and stable catalysts. In this case, the problem has occurred and needs to be resolved as follows. So in this research, catalyst ratio for CO_2 conversion was studied. The study focused on catalyst ratios that are used for the conversion of CO_2 to methane (CH_4) by using the methanation process. Nickel-Alumina (Ni-Al) was used as the based catalyst and Magnesium (Mg) as the promoter by investigating the most optimum catalyst ratios that affected the methane product.

2. MATERIAL AND METHODS

The research was conducted in the Operations Unit Laboratory and the Chemical Engineering Analysis Laboratory, Politeknik Negeri Sriwijaya. In this research, the CO_2 conversion to methane (CH_4) has been processed on a laboratory scale, in order to study the effect of catalyst ratio and promoter. Tools and equipments used as follows: blender, rubber ball, erlenmeyer 3 bar 500 ml, 500 ml beaker, 200 ml beaker, hotplate magnetic stirrer, watch glass, analytical balance, 500 ml measuring flask, glass stirrer, measuring pipette, plastic packaging, RO hose pipe, transparent hose pipe, spatula, tube CO_2, thermogun. Material used are aquadest, demineral water, magnesium powder, catalyst (nickel and aluminium).

The parameters observed in this study are the characteristics of the products based on variations in the ratio of catalysts and amount of promoter used. In this research CO_2 react with H_2 to produce methane (CH_4) by using Ni-Al based catalyst and Mg promoter. The reaction was conducted in a lower temperature and atmospheric pressure under laboratory scale. The output product (CH_4) was analyzed using Multi Gas Detector Analyzer.

3. RESULTS AND DISCUSSIONS

The results of the analysis of the product of the processing of CO_2 gas into methane gas using variations of the catalyst nickel, alumina, and the magnesium powder as promoter, then be analyzed to find out how much methane gas content is produced. In this research, 10 samples were used to analyze the effect of catalyst ratio on the methanation process, the variation of sample, catalyst ratio and yield product can be seen in the table 1.

Table 1. Yield Product based on Catalyst Ratio

Sample	Catalyst Ratio	Gas Yield	
	(Ni-Al : Mg)	CH_4 (%)	CO_2 (%)
Sample 1	1:1:1	0,92	0,35
Sample 2	1:2:1	0,99	0,30
Sample 3	1:3:1	1,25	0,29
Sample 4	2:1:1	1,39	0,27
Sample 5	3:1:1	1,45	0,25
Sample 6	1:1:2	1,48	0,25
Sample 7	1:2:2	1,55	0,24
Sample 8	1:3:2	1,70	0,23
Sample 9	2:1:2	1,73	0,22
Sample 10	3:1:2	1,82	0,20

Table 2. Catalyst and Promoter Content After Methanation Process

Sample Name	Analysis Method	Result (%)		
		Ni	Al	Mg
Sample 1	X-Ray Diffraction (XRD)	33,6	31,9	34,5
Sample 2		89,0	9,5	1,5
Sample 9		25,1	21,3	53,6
Sample 10		92,3	5,7	2,0

3.1 Analysis of the Methane content (CH_4) from the Methanation Process

Based on the value of methane gas in Figure 1, all samples resulting from the methanation reaction showed increased. This is due to the variation of catalysts and promoters from the existing samples. Sample 10 showed the result of 1.82% methane which is the most optimum value of all the existing samples. The results of methane gas from Sample 10 also showed that the methanation reaction was affected with the addition of a magnesium promoter which kept the catalyst from reacting quickly so that more methane gas was produced.

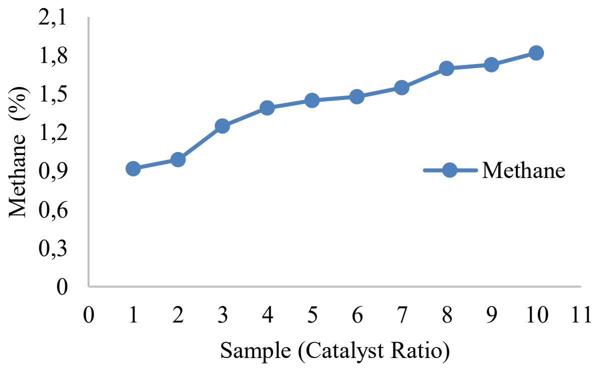

Figure 1. Methane Content based on Sample Variations

From the figure above indicated that the variation of the catalyst and promotor of the 10th sample, 3g Nickel + 1g Alumina + 2g Magnesium, is the most optimum variation with a value of 1.82%, but the methane product has relatively low.

3.2 Analysis of the CO_2 from the Methanation Process

Carbon dioxide (CO2) is the main component used in the methanation reaction. Carbon dioxide flowed through the RO hose from the CO_2 tube into the Erlenmeyer flask which then contact with H_2 and used the catalyst and promoter dissolved in NaOH solution. The lowest CO_2 content in product indicates the greater the CO_2 that reacts with H_2 by using catalyst-promoter and the greater the methane gas produced.

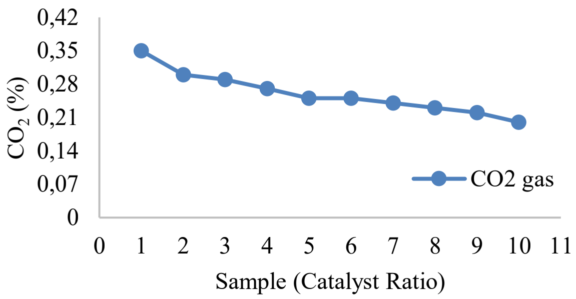

Figure 2. CO_2 Content based on Sample Variations

Based on figure 2, the CO_2 residual from methanation process is relatively low around 0,2-0,35%, it means the more CO_2 is converted to product, but in this research the methane product is still low. it can be concluded that the variation of catalyst and promoter for the 10th sample 3g nickel + 1g alumina + 2g magnesium is the most optimum variation because the CO_2 value on the product has the lowest percentage compared to other variations.

3.3 Nickel (Ni) Substance Analysis for Catalyst on the Methanation Process

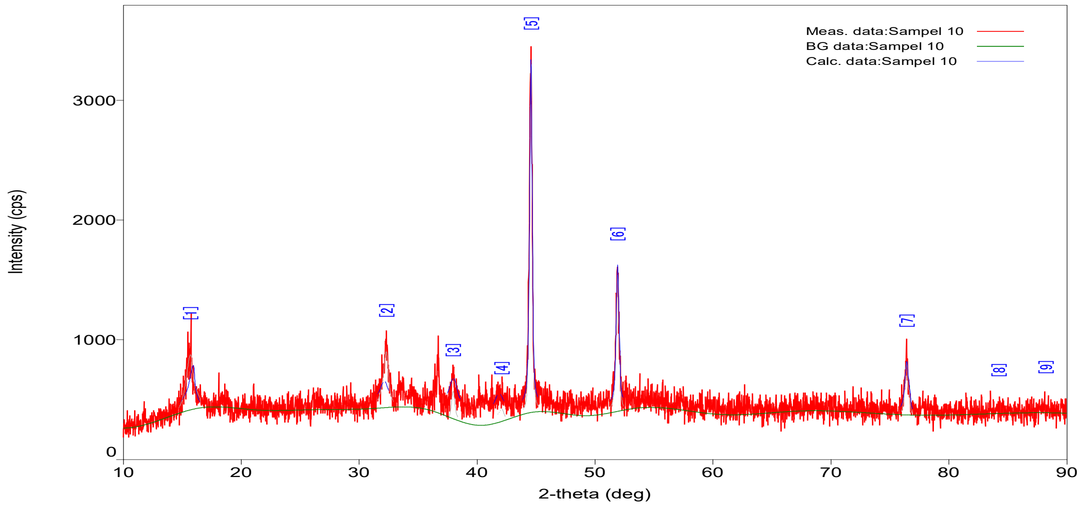

Figure 3. Nickel XRD Test Results for Variation of Sample-10

Figure 3 showed the composition of the catalyst substances, namely nickel, alumina, and magnesium. The graph shows a large relevant number, 92.3% for nickel composition. This shows that in the sample 10 variation, nickel can maintain its composition, assisted by the amount of nickel in the 10 sample variation, which is 3g. This also has an effect on the mechanism of the reaction, which can take place more optimally in comparison to other sample variations. From this analysis it can be concluded that Sample 10 is the most optimal sample variation in terms of residual nickel content after the methanation process compared to other sample variations.

3.4 Alumina (Al) Substance Analysis for Catalyst on the Methanation Process

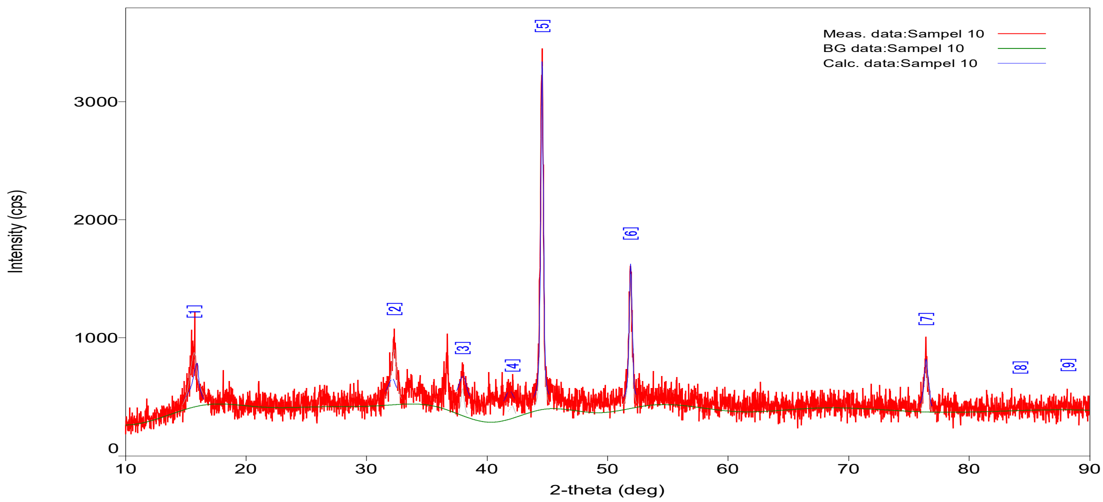

Figure 4. Alumina XRD Test Results for Variation of Sample-10

In figure 4, diagram 3 shows the composition of the substances, nickel, aluminum oxide and magnesium. In the composition of alumina, the diagram shows a relatively small number of 5.7%. Due to the following sample variation of 10, the amount of alumina used is also smaller when compared with the value of the catalyst content of other sample variations. Lifting the alumina from sample variation 10 still shows good results because it is still relatively higher than the value of magnesium which reacts with $NaHCO_3$. From this analysis it can be concluded that sample variation 10 is the most optimum sample variation in the remaining alumina content after the methanation process compared to the another sample.

3.5 Magnesium (Mg) Substance Analysis for Catalyst Promoter on the Methanation Process

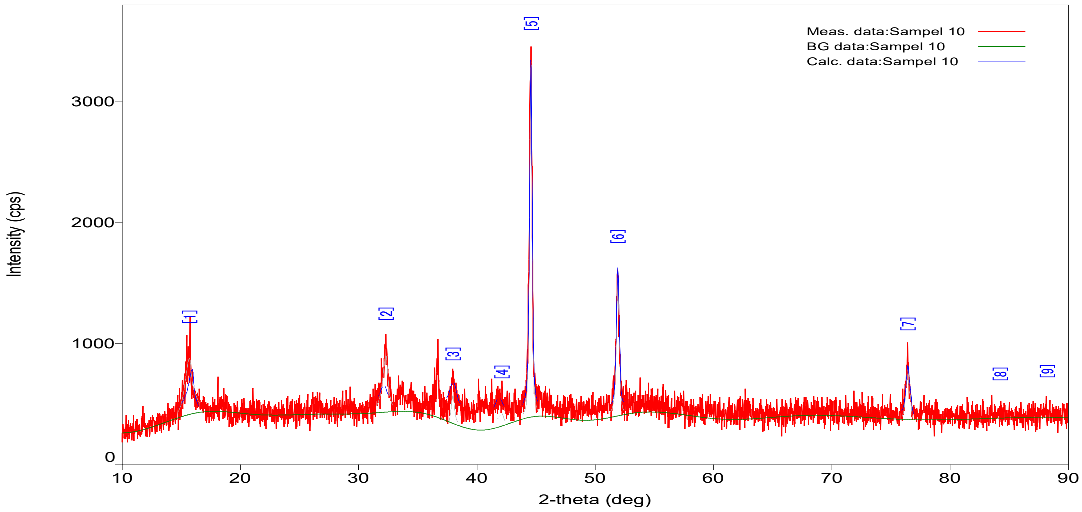

Figure 5. XRD Magneium Test Results for Variation of Sample-10

Figure 5 shows the composition of the substances, nickel, alumina and magnesium. In the composition of magnesium, the diagram shows the lowest number, which is 2.0%. This is because in the methanation process, magnesium participates in the reaction in the formation of methane gas. When compared with the value of the catalyst content of other sample variations, the magnesium from the 10 sample variations still shows the smallest results compared to the other sample variations. Based on the analysis, it can be concluded that the sample variation of 10 is the most optimum sample variation in the remaining alumina content after the methanation process compared to other sample variations.

From the analysis performed, it can be concluded that sample variation 10 is the most optimal variation with the highest amount of methane gas formed, the lowest amount of carbon dioxide gas remaining, and the best remaining catalyst and promoter composition compared to other sample variations. This variation of the 10 samples can also prove that the methanation process carried out in this study was successful as indicated by the presence of methane gas in the output gas product.

4. CONCLUSIONS

Based on the results of research and discussion can be interpreted as follows: Nickel, Alumina, and Magnesium as catalysts and promoters have an effect on the yield of Methane Gas obtained. Meanwhile, the results of the reduced catalyst after the methanation process were influenced by the Mg promoter which resulted in an increase in the value of the obtained methane gas. The most optimum Nickel-Alumina catalyst variation in the methanation process is for 10^{rh} sample, which is a combination of 3g nickel + 1g alumina + 2g magnesium. Gas products of other methanation processes using this variation produce the largest methane gas, which is 1.82% Methane gas has been produced from the methane process, but the methane gas produced is still minimal due to the relatively low temperature.

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