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# Analysis of water-ethanol-gasoline (RON 88) compositions in one phase substance-using triangular graph

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**Abstract.** The present work is aimed at analysing the compositions of the water, ethanol, and gasoline which has *Research Octane Number*/RON was 88 forming a stable emulsion (one phase) employing a ternary graph. When the mixture process, the blended fuels consisted of water-ethanol-gasoline were successfully prepared in which they were formed in one phase. Ethanol was derived from *Arenga pinnata* liquor which is locally called *cap tikus* using a home-made reflux distillation filled by packing materials. Ethanol obtained were differing their concentration that depended on the column temperature set. It was found that the purities were ranged from 80 to 96% and the higher column temperature was chosen the lower concentration was obtained. Each aqueous ethanol was blended with gasoline to obtain a homogenous solution. For ethanol 80%, compositions of water, pure ethanol, and gasoline were observed at 18, 74, and 8 (%v/v), and 22, 70, and 7 (%w/w). While ethanol 96%, the compositions ratios were 1:22:77 (%v/v) and 1:23:76 (%w/w). The ranges of pure ethanol, gasoline, and water in which they formed one phase solution were recorded at 23-70%, 7-76%, and 1-22%. The work found that substance was in one phase if the wet ethanol keeps being added. When the ethanol composition has decreased the substance was separated into wet ethanol and gasoline. The minimum ethanol dissolved completely into gasoline was of 80%.

## 1. Introduction

The world is facing a difficult time caused by the dwindling of the petroleum reserved and the increasing of the atmospherically temperature called (*global warming*). The utilization of renewable resources which are processed into biofuels must be developed massively around the world. The biomass (lignocellulose and starch) have been attracting many scientists to improved becoming modified materials and food [1-7]. The treated biomass as stated previously were more easy to convert them into sugars [8] and then were fermented into alternative energies such as the bioethanol [9], hydrogen gas [10], and solid fuel [11]. The other green fuel derived from a renewable resource and had been produced at the industrial scale was biodiesel [12].

Indonesia still uses fossil-based fuels as the main energy source in the transportation sector, electrical generations, and industrial sector. On the other hand, their reserves are decreasing and will be run out in the coming years because are not renew able. The blended fuels are an alternative solution to substitute a part of petroleum.

The blended fuels have been investigated for years by authors and reported by inventors previously as printed in journals and patent documents. The study of diethyl ether and ethanol added to biodiesel/diesel blends was evaluated on performance, emission, and combustion characteristics. The result showed that CO emission was lower than the non-blended fuels [13]. The feasibility study of biodiesel/diesel blends in which the biodiesel ratio was studied. The work showed that the increment of 10% biodiesel, the energy decreased at 1.42%. The engine test, however, there was no significant difference if compared to the low ratio [14].

The smoke characteristics of the four-stroke engine employing an ethanol-gasoline fuel which ethanol part was 10% (v/v), E10, was analyzed. It was found the CO and HC emission was lower than that of pure gasoline. The smoke analysis showed the ethylene, acetaldehyde, and ethanol emissions were bigger compared to than unleaded gasoline engine [15]. The effect of ethanol-gasoline blends for SI engine especially on cold-start emission. The results suggested that the 5, 10, 20, and 30 ethanol blends with gasoline, the engine was started well and HC and CO emissions were decreasing. At E40 the engine work faced a problem because the air-fuel mixture was not proportional [16].

The blended fuels, biodiesel-diesel, biodiesel-ethanol, and ethanol-gasoline also were reported in many document patents. The fuel blends, diesel fuel oil and a $C_3$ (excluding n-propanol)-$C_{32}$ organic alcohol, were disclosed as stated in US Patent No. 5,720,784. The blend fuels of diesel, ethanol and a coupling agent were discovered documented in US Patent No. 7,357,819 B2. The invention revealed the coupling agent comprises: 2-ethyl hexanol; fatty alkanolamides; and one or more fatty acids; wherein one or more fatty acids are present in the coupling agent.

Dissolution of water and pure ethanol in gasoline was investigated whereby ethanol was derived from Arenga pinnata. The work investigated the soluble state of water-pure ethanol-gasoline in normal conditions [17]. However, the previous work did not investigate the compositions of three components in one phase substance. As mentioned previously in references survey was mainly describing the blend fuels in which the purity ethanol was close to un-hydrous alcohol and the ethanol-fossil fuel bonds must be other agents, surfactants and coupling agents.

The present study aims to study the blend fuels of water-ethanol-gasoline in one phase whereby alcohol concentrations were ranged from 80 to 96%. The composition of water was taken from aqueous ethanol by multiplying the purity with a total volume and divided by volume of three components. The procedure was briefly summarized: The preparation of palm sap, the ethanol yeasting, and distillation.

## 2. Materials and Methods

Ethanol used in this study was derived from liquor which was produced by the farmer. The sap consisting of sugar 14% was tapped from *Arenga pinnata* and kept in a plastic container in which it occurred a fermentation for 3-5 days. The yeasted solution that its ethanol concentration was of 7% was poured inside the boiler and heated until its boiling temperature. The vapor was channeled into a simple distillation and condensed into the liquid phase and the ethanol average purity of liquor obtained was of 40%.

The liquor was purchased and then continued to increase its purity ranging 80 to 96% employing a reflux distillation as shown in Figure 1. The liquor was poured inside the boiler and the temperature was increased until its boiling. The liquor volume filled in the boiler was of 0.75 of total volume, while the packing materials were 80% of column volume. The length of a reflux column was 2 meters and diameter was of 2 inches. The purity of ethanol produced was depending on the column temperature, ethanol content in liquor, and packing materials. The vapor rose to the reflux column and was occurred a separation between ethanol and water and then ethanol dropped into a flask and was isolated.

The blending procedures were the following: The gasoline denoted with gas was measured at 15 mL and poured in Erlen-Meyer glass. In the industrial scale, the unit can be extended into either of a liter or kiloliter. Firstly, the aqueous ethanol assigned by Aq. Et with purity 80% was mixed with gasoline. In a similar volume, two components were separated and when the wet ethanol was added continually the gasoline was starting dissolved. The components were not distinguished at wet ethanol added was of 75 mL. The volume of pure ethanol was obtained by employing a formula %x volume of Aq. ethanol, while pure water using a relation of (100%-% Aq. ethanol) x volume of Aq. ethanol. The composition was calculated by ratio equation of volume of the certain component divided by total volumes. In this study also described the composition in the triangular graph.

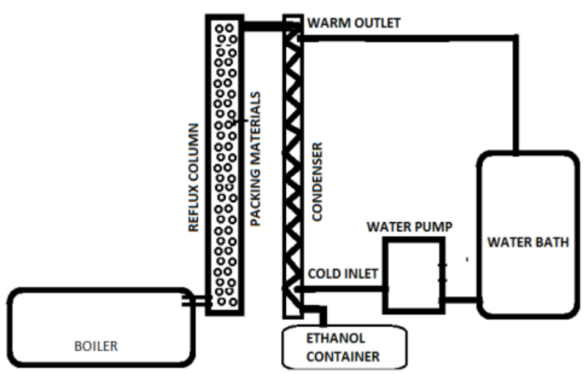


Figure-1. The reflux distillation design

## 3. Results and Discussion

Table 1 shows the composition of one phase of water (Wat), ethanol (Et), and gasoline (Gas) which has RON 88. Three components could be forming one phase substance but the composition must be exact. The 175 mL of ethanol 80% could be dissolved completely with 15 mL gasoline. The composition of aqueous ethanol and gasoline in one phase was recorded at 92.11 and 7.89%. The composition in %w/w is shown in the right column as displayed in the table and in the text just described. The ethanol 81% formed a homogenous substance in which percentages of water, pure ethanol and gasoline were of 17.42, 74.25, and 8.33, while at 85% compositions were of 13.33, 75.56, and 11.11%. It was discovered that the higher ethanol concentration employed was the higher gasoline-ethanol used.

If ethanol purity was increased to 90% the volume needed of three components was changed widely. To form one phase was needed gasoline 10 mL, wet ethanol 30 mL, or water 3 mL or in percentage compositions were of 7.50% water, 67.50% pure ethanol, and 25.50% gasoline, meanwhile

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the compositions (in %w/w) were of 9.00, 67.00, and 24.00%. When ethanol increased slightly to 92%, the volume ratio of gasoline and aqueous ethanol was of 10:21 which were similar to compositions ratio 69:31 (w/w).

The compositions of water, pure ethanol and gasoline were recorded at 3.82, 50.73, and 45.45% if wet ethanol was of 93% that was equivalent to volume and weight ratios observed at 0.85:11.16:10 and 5.00:51.00:44.00. The weight and volume ratios changed to 4.00:45.00:51.00 (%w/w) and 0.54:8.46:10 when ethanol concentration went up to 94%. While the compositions were noted at 2.84:44.53:52.63 (%v/v).

**Table 1.** Compositions of water, ethanol, and gasoline (RON 88) in one phase substances

| Et Con (%) | Volume (mL) | | | | Composition (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (V/V) | | | (W/W) | | |
| | Gas | Aq.Et | Wat in Aq.E | Pure Et | Wat | Et | Gas | Wat | Et | Gas |
| 80 | 15 | 175 | 35.00 | 140.00 | 18.42 | 73.68 | 7.89 | 22.00 | 70.00 | 7.00 |
| 81 | 10 | 110 | 20.90 | 89.10 | 17.42 | 74.25 | 8.33 | 21.00 | 71.00 | 8.00 |
| 82 | 10 | 100 | 18.00 | 82.00 | 16.36 | 74.55 | 9.09 | 20.00 | 72.00 | 8.00 |
| 83 | 10 | 90 | 15.30 | 74.70 | 15.30 | 74.70 | 10.00 | 19.00 | 72.00 | 9.00 |
| 84 | 10 | 85 | 13.60 | 71.40 | 14.32 | 75.16 | 10.53 | 18.00 | 73.00 | 10.00 |
| 85 | 10 | 80 | 12.00 | 68.00 | 13.33 | 75.56 | 11.11 | 16.00 | 73.00 | 10.00 |
| 86 | 10 | 65 | 9.10 | 55.90 | 12.13 | 74.53 | 13.33 | 15.00 | 73.00 | 12.00 |
| 87 | 10 | 60 | 7.80 | 52.20 | 11.14 | 74.57 | 14.29 | 14.00 | 73.00 | 13.00 |
| 88 | 10 | 55 | 6.60 | 48.40 | 10.15 | 74.46 | 15.38 | 13.00 | 73.00 | 14.00 |
| 89 | 10 | 42 | 4.62 | 37.38 | 8.88 | 71.88 | 19.23 | 11.00 | 71.00 | 18.00 |
| 90 | 10 | 30 | 3.00 | 27.00 | 7.50 | 67.50 | 25.00 | 9.00 | 67.00 | 24.00 |
| 91 | 10 | 28 | 2.52 | 25.48 | 6.63 | 67.05 | 26.32 | 8.00 | 67.00 | 25.00 |
| 92 | 10 | 21 | 1.68 | 19.32 | 5.42 | 62.32 | 32.26 | 7.00 | 62.00 | 31.00 |
| 93 | 10 | 12 | 0.84 | 11.16 | 3.82 | 50.73 | 45.45 | 5.00 | 51.00 | 44.00 |
| 94 | 10 | 9 | 0.54 | 8.46 | 2.84 | 44.53 | 52.63 | 4.00 | 45.00 | 51.00 |
| 95 | 10 | 4 | 0.20 | 3.80 | 1.43 | 27.14 | 71.43 | 2.00 | 28.00 | 70.00 |
| 96 | 20 | 6 | 0.24 | 5.76 | 0.92 | 22.15 | 76.92 | 1.00 | 23.00 | 76.00 |

The ethanol 95 and 96% were obtained more difficult compared to that of below 94% since the column temperature should be controlled tightly. In the blending process, however, those are very easy to dissolve into gasoline. The ethanol needed for 95 and 96% were only 4 and 6 mL compared to gasoline recorded at 10 and 20 mL. The percentage of water, pure ethanol, and gasoline were of 1.43, 27.14 and 71.43 (%v/v) and 2.00, 28.00, and 70.00 (%w/w). The compositions varied when ethanol purity to 96% and was observed at 0.92, 22.15, and 76.93 and 1.00, 23.00, and 76.00.

Fig. 2 shows the triangular diagram of substances, water-ethanol-gasoline (RON 88) in one phase in which their compositions are assigned with solid circles and the data included in a graph were only compositional in %v/v. The solid circle as shown was the compositions of water, ethanol, and gasoline whereby they were just formed a soluble liquid. The region located on the right line (in front of the reader) was one phase whereby three components were in one phase. On the other hand, the region situated on the left line was two phases aqueous ethanol and gasoline was separated. It was found that the separation was gradually depending on ethanol composition.

The study showed the one phase fuel consisting of the polar (water/ethanol) and nonpolar (gasoline) substance was possible to be formed. The ethanol role is very important to connect between water and gasoline. As known the ethanol consists of two parts, R ($C_2H_5$-) and (-OH that could bond nonpolar in fossil fuel and polar branches of water.

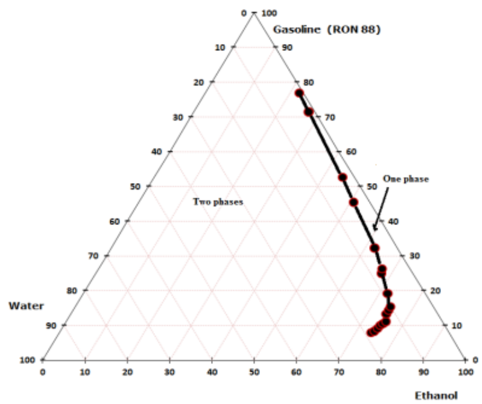


Figure 2. The triangular diagram of water-ethanol-gasoline (RON 88) in one phase in normal condition

For it has two parts as previously described, the ethanol could be functioning as a surfactant which was a bridge connecting gasoline and water. The bond is mainly coming from electrical interaction between positive- and negative charges. When the gasoline composition was larger than ethanol the components were separated since the bond strength could be weaker than the oil weight. The most important findings in this study are the composition is the critical point in the successful blending. The previous work which was comparable with the present study was carried to blend a gasoline and a technical ethanol 96% as reported by authors [18]. It was indicative that the aqueous ethanol could be blended with gasoline to form one phase substance as alternative energy (see Figure 2).

## 4. Conclusion

The aqueous one phase emulsion of the water, pure ethanol and gasoline (RON 88) were successfully blended in which ethanol was produced from *Arenga pinnata* sap. The palm juice was yeasted into a liquor which consisted of ethanol and water. The ethanol was separated using a reflux distillation and produced ethanol with concentration 80-96% depending on a column temperature. It was found that aqueous ethanol which still had water could dissolve easily with gasoline in a certain composition. The ethanol 80% was a minimum concentration to form one phase solution with gasoline. The data showed that the higher ethanol purity added into the mixture was the less ethanol needed to mix with gasoline forming one phase solution. It was discovered if ethanol composition increased continually after one phase formed the components were not separated into two phases.

## Acknowledgments

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