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The Effects of Ethylene Glycol to Ultrapure Water on Its Specific Heat Capacity and Freezing Point

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ABSTRACT

In this article, the effect of specific heat capacity and freezing point of the ultrapure water and ethylene glycol mixture as a car radiator coolant is being studied and conducted. Ethylene glycol is an organic compound with the formula (CH2OH)2. It is mainly used as the car radiator because its antifreeze properties. Another aspect of using the ethylene glycol is that they have a higher boiling point. Hence, they do not get vaporized easily inside the radiator. They also have higher specific heat capacity and capable of transferring more heat from the engine as compared to water. The research conducted to study the effect of ethylene glycol as a car radiator coolant when it is mixed with ultrapure water. This technique is aided with Differential Scanning Calorimetry or DSC6000. From the result, it is found that the ultrapure water and ethylene glycol mixture with higher specific heat capacity and lower freezing point is a good car radiator. The results from the experiments conducted using DSC6000 are that the specific heat capacity and the freezing point temperatures of the ethylene glycol-ultrapure water will vary depending on the ratio of the mixtures used. The data and results obtained from DSC6000 are in the form of graphs in which calculations will be done using mathematical formulas and equations in order to obtain the specific heat capacities and freezing point temperatures for each of the ratios used for the ethylene glycol-ultrapure water used.

KEYWORDS: Ethylene Glycol, Ultrapure Water, Antifreeze, Freezing Point, Specific Heat Capacity.

INTRODUCTION

Conventional coolants such as ethylene glycol and water have been widely used in an automotive car radiator coolant for many years [3]. Their performance as coolants for car radiators depends on their heat capacity, freezing point and oxidative induction time. As reported by [5], ethylene glycol has been used majorly as medium for convective heat transfer in, such as car radiators, liquid cooled computers, chilled water air conditioning systems and the like. For car radiators, water is a much better engine coolant. However, the problem with water is that it freezes or boils at extreme temperatures. Because of this problem, the application of nanoparticle in the mixture of water and anti-freezing materials (in this case, ethylene glycol) as the base fluid is conventionally used in car radiators. The additions of anti-freezing materials to water can help to increase the boiling point and reduce the freezing point of the coolant. Anti-freezing agents like ethylene glycol can withstand much greater temperature extremes. Most of the properties of water are retained but the ability to withstand extreme temperatures comes from ethylene glycol.

As reported by [5], different water percentage in the water-ethylene glycol mixture resulted in different boiling point elevation and freezing point depression. A pure ethylene glycol itself has a freezing point at about -12℃, but when mixed with water, the freezing point of the mixture is depressed significantly. As an example, a mixture of 60% ethylene glycol and 40% water can withstand cold temperatures up to -45℃. The boiling point for the mixture however increases monotonically as the percentage of ethylene glycol in the mixture increases. It is not only the addition of ethylene glycol to the water lowers the freezing point, but also elevates the boiling point for the aqueous mixture as well. The operating range for the mixture is broadened on both ends of the temperature scale. Having desirable thermal characteristics such as low freezing point, high boiling point, better stability over a wide range of temperatures and good thermophysical properties of ethylene glycol is a very popular anti-freeze and heat transfer fluid in numerous commercial and industrial applications [8].

According to [3], these heat transfer fluids such as the mixture of water and ethylene glycol offer low thermal conductivity. With the advancement of nanotechnology, a new generation of heat transfer fluids dubbed “nanofluids” are found to have higher thermal conductivity than that of conventional coolants. In [10] reported that about 15-40% of heat transfer enhancement can be achieved by using various typed of nanofluids.

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In [9] stated that ethylene glycol a commonly used while there are many choices of heat transfer fluids for base fluids, due to their attractive price. However, both have obvious shortcomings which is the water has relative high thermal conductivity (0.6 W/(mK) at 20℃), but it will freeze or boil at extreme temperatures, while the ethylene glycol has a wider temperature range for operation, but the thermal conductivity for ethylene glycol is only 0.253 W/(mK) at 20℃. Hence, the mixture of ethylene glycol and water is always commercially used as heat transfer fluid in different energy system to retain good heating or cooling ability of water. It is reasonable that the mixture of water and ethylene glycol based nanofluids has attracted much attention from scientific workers. The study of the volume concentration and viscosity was being investigated by [4] who reported experiment observations on the effect of the temperature and it was found it that the tested nanofluids behave as a Newtonian fluid [1]. The results indicated that thermal conductivity of nanofluids increased with increase of volume concentrations and temperatures. The same occurrence also happened to viscosity of nanofluids increased with increased of volume concentrations but decreased with temperature. They found that the thermal conductivity of nanofluids with more water as base fluid was higher and the increasing temperature also lead to a higher thermal conductivity and the viscosity of nanofluids increased with increasing the concentration of ethylene glycol.

Since the water is probably one of the most efficient heat transfer fluids, because it combines high heat capacity and thermal conductivity with low viscosity and the ethylene glycol can work below the water freezing point or above its boiling point, they are commonly used as the base fluids. According to [2], water also have disadvantages such as its limited operating temperature range, high vapour pressure and corrosivity. Besides, the thermal conductivity if ethylene glycol is lower than the water, glycol mixture are used as heat transfer fluids instead of pure ethane-1, 2-diol.

The objective for this experiment is to determine the specific heat capacity and freezing point to find out which ultrapure water-ethylene glycol mixture ratio is the best to be used as coolant for car radiator. The addition of nanoparticles into the mixture is to study its effects on the specific heat capacity and freezing point of the mixture. According to previous studies by [3], the addition of nanoparticles will enhance the coolant properties of the ultrapure water-ethylene glycol mixture. However, in this experiment only the properties of the base fluids, which were ethylene glycol and ultrapure water were studied.

METHODOLOGY

Sample Preparation of Ethylene Glycol with Ultrapure Water

About nine samples ultrapure water and ethylene glycol mixture was prepared but with a different ratio of ultrapure water and ethylene glycol. Each bottle contains 20 ml of the mixture. The ratio of ultrapure water to ethylene glycol are 10:90, 20:80, 30:70, 40:60, 50:50, 60:40, 70:30, 80:20 and 90:10

Specific Heat Capacity Determination

The specific heat capacity for each of the mixtures was determined by using the differential scanning calorimetry, PerkinElmer DSC6000. Differential scanning calorimetry in a temperature range from 190 to 280 K, with nitrogen gas as purge gas (50 mL min ^{1}). The 10:90 ratio of ultrapure water and ethylene glycol mixture were taken from the plastic container by using a micropipette equipment. The mixture was then placed into an alum pan. The mass of the mixture taken was then measured until it reached 10mg by using the milligram balance, model no. AD 6000. The pan was then covered and placed into the DSC. The DSC6000 software method editor was then configured as following:

1) The DSC will maintain the temperature at 25℃ for four minutes.
2) The DSC will then heat up to 80℃ and will remain at 80℃ for five minutes.
3) The DSC will then be cooled down to the starting temperature (25℃).

The readings for the heat capacity were then recorded after the temperature drops down to less than 50℃. Then, the steps were repeated for each sample with the ratio of ultrapure water to ethylene glycol mixture are 20:80, 30:70, 40:60, 50:50, 60:40, 70:30, 80:20 and 90:10.

Freezing Point Determination

The freezing point for each of the mixtures was measured using the differential scanning calorimetry technique, by using PerkinElmer DSC6000. The 1:9 ratio of ultrapure water-ethylene glycol mixture were taken from the plastic container by using a micropipette equipment. The mixture was then placed into an alum pan. The mass of the mixture taken was then measured until it reached 10mg by using the milligram balance, model no. AD 6000. The pan was then covered and placed into the DSC. The DSC6000 software method editor was then configured as following:

1) The DSC will be hold for 1.0 min at 15℃.
2) The DSC will then cool down to -110℃ at rate 10℃/min.
3) The DSC will heat up from the -110℃ to 15℃ at rate 10℃/min.

The readings for the heat capacity were then recorded. Then, the steps were repeated for each sample with the ratio of ultrapure water to ethylene glycol mixture are 20:80, 30:70, 40:60, 50:50, 60:40, 70:30, 80:20 and 90:10.

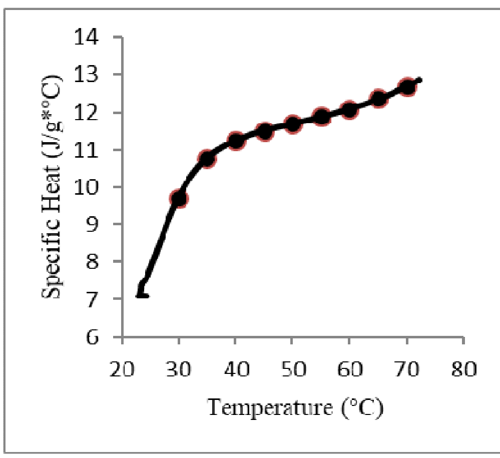
RESULTS AND DISCUSSION

Specific Heat Capacity

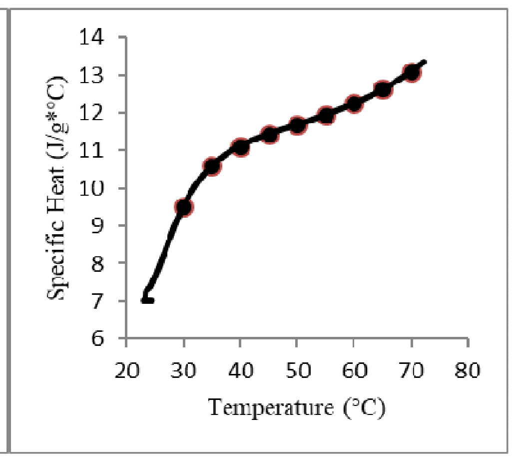
Based on Figure 1 (A, B, C, D, E, F, G, H and I) the result of specific heat capacity is increased when the temperature is increased. It shows that the specific heat capacity depends on the temperature. Based on Figure 2, at temperature 70°C, it shows that specific heat capacity of 8ml of ethylene glycol mix with the water has the highest specific heat capacity which is 13.2130 J/g*°C. The lowest specific heat capacity obtained was the mixture of 8ml of ethylene glycol and 12ml of ultrapure water. In this experiment, the specific heat capacity was observed in the sample containing only ethylene glycol and ultrapure water mixture but depends on the ratio at every temperature. Therefore, when using less ethylene glycol, it will produce higher specific heat capacity.

Figure 2 illustrates the relationship between temperature and specific heat capacity. As the temperature increases, the specific heat capacity of each sample will also increase. This is because when the sample heat up in the DSC6000, the temperature will be increased as well. Hence, the molecules movement in the mixture also increase. Therefore, the kinetic energy between the particles will be higher and collide with each other and produce enough energy to allow the rotation and vibration to occur.

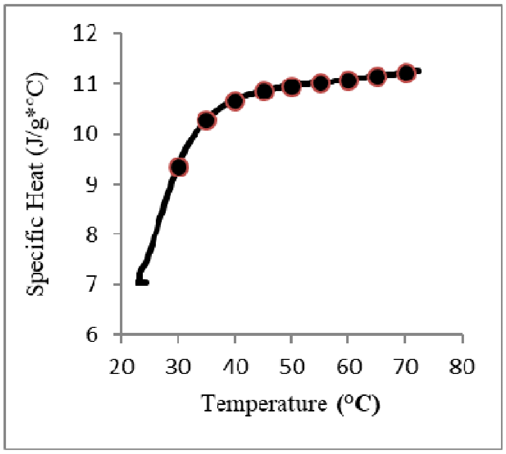
From the graphs made using the data taken from the DSC6000, it is found that as the volume of ethylene glycol increases, the area under curve for each of the graphs decrease. The areas under the curve for each graph were obtained from calculations using the Simpson's Rule. The area under the curve of the graphs signifies the specific heat capacities for each of the samples. This fact strongly supports the above statement that as the volume of ethylene glycol in the mixture increases, the specific heat capacity of the mixture will decrease. This also means that the mixture's ability to absorb heat decreases as the volume of ethylene glycol in the mixture increases. Therefore, from the above results and the data obtained throughout the experiment carried out on the DSC6000, it is concluded that too much volume of ethylene glycol in a coolant mixture will result in the said mixture to be less efficient in cooling car radiators through heat absorption. This is because a lower specific heat capacity absorbs less heat energy to increase the temperature of a substance by 1 °C.



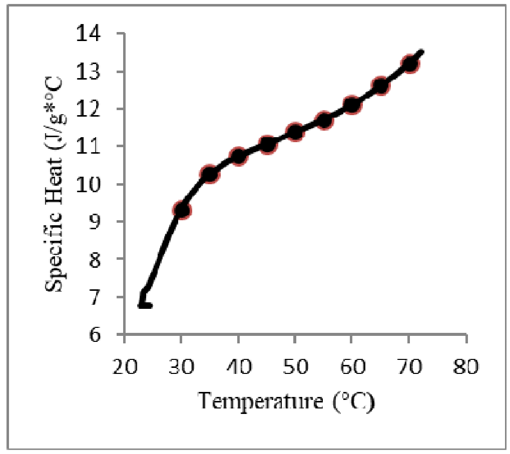
(A) 2ml of ethylene glycol mix with 18ml water



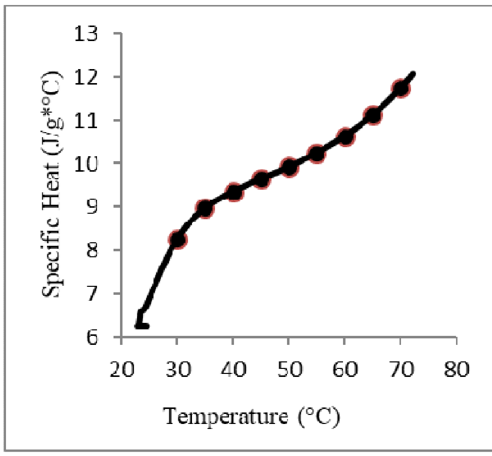
(B) 4ml of ethylene glycol mix with 16ml water



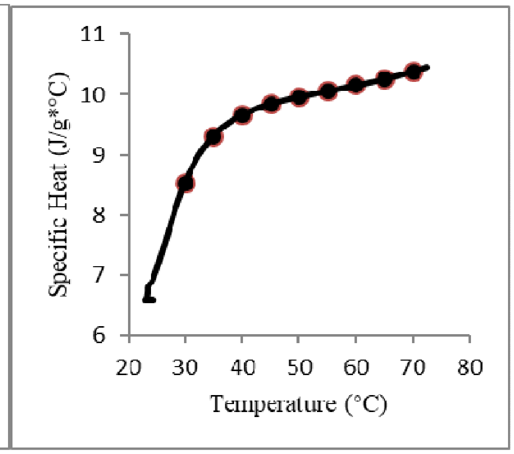
(C) 6ml of ethylene glycol mix with 14ml water



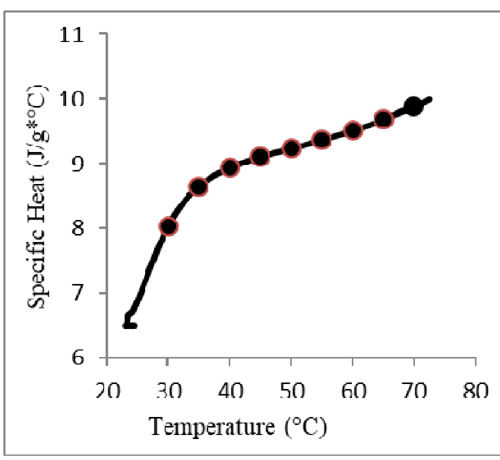
(D) 8ml of ethylene glycol mix with 12ml water



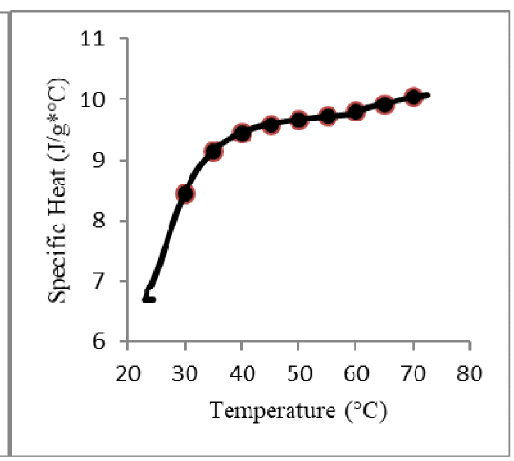
(E) 10ml of ethylene glycol mix with 10ml water



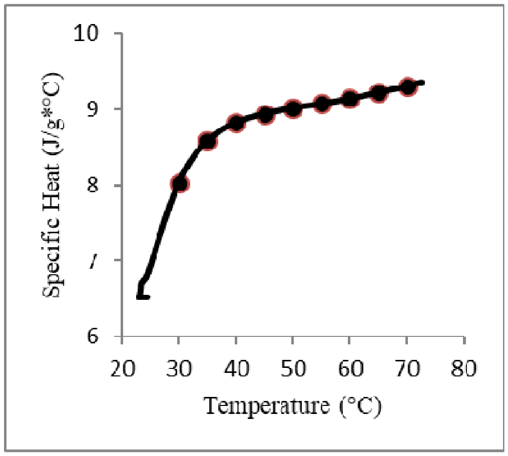
(F) 12ml of ethylene glycol mix with 8ml of water



(G) 14ml of ethylene glycol mix with 6ml of water



(H) 16ml of ethylene glycol mix with 4ml of water



(I) 18ml of ethylene glycol mix with 2ml of water

Figure 1: Specific heat capacity ethylene glycol mix water with different ratio against temperature

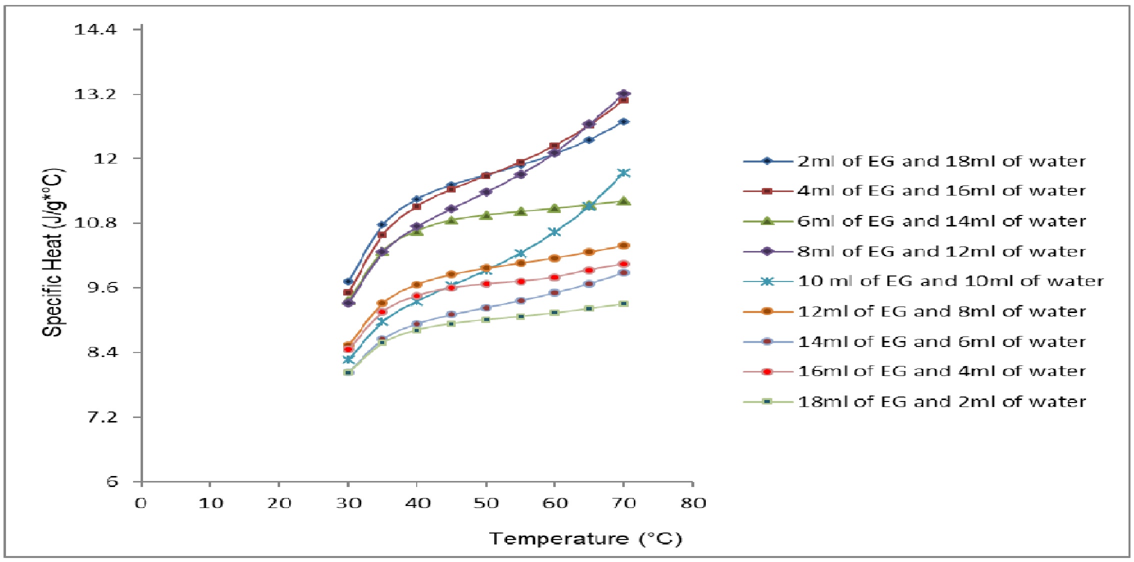


Figure 2: Comparison specific heat capacity against temperature between the samples

Freezing Point

In this study, the freezing point for ethylene glycol mix with ultrapure water with different ratio was determined and the result was recorded in the table below. Since our DSC6000 have a limitation which can only check the sample temperature for freezing point to only -50°C, the freezing point obtained until the ratio of ethylene glycol to ultrapure water is 40:60. While for the other ratio which is 50:50, 60:40, 70:30, 80:20 and 90:10, the result was predicted by using equation from the graph.

From the graphs made using the data taken from the DSC6000 as shown in Figure 3, it is found that as the volume of ethylene glycol increases, the freezing points of the coolant mixtures decreases. For the mixtures with volumes of 10 ml to 18 ml, the freezing points could not be obtained due to the limitations of the DSC6000. The DSC6000 can only measure temperatures up to -50℃, therefore the freezing point temperatures for mixtures with ethylene glycol volumes of 10 ml, 12 ml, 14 ml, 16 ml and 18 ml were unobtainable with the lowest freezing point obtainable being -45.97℃for the ethylene glycol with the volume of 8 ml.

By plotting a graph of freezing point temperature versus the volume of ethylene glycol at 2 ml, 4 ml, 6 ml and 8 ml as shown if Figure 3, a linear relationship that best fit between data was calculated with a linear regression of $R^2 = 0.9604$. Thus, an equation is proposed to predict the freezing point temperatures of mixtures with ethylene glycol volumes of 10 ml, 12 ml, 14 ml, 16 ml and 18 ml which is as stated below

$$Y: -3.738x - 14.21 \qquad (1)$$

whereY: Freezing point temperature, ℃ and X: Ethylene glycol volume, ml.

Table 1. Freezing point of ultrapure water and ethylene glycol mixture with different ratio

Volume of Mixture (ml)	Freezing Point (˚C)
2	-22.79
4	-28.82
6	-34.04
8	-45.97
Predicted	
10	-51.595
12	-59.071
16	-66.547
18	-81.499

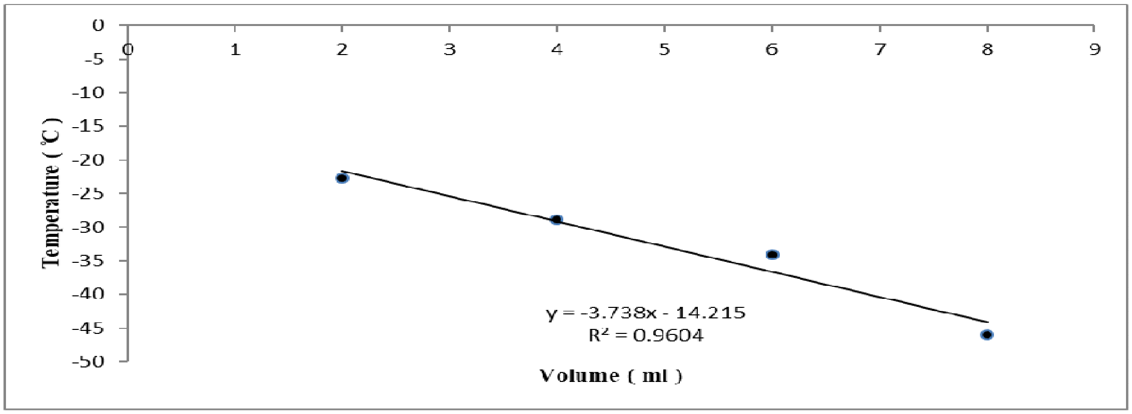


Figure 3: Comparison of freezing point against different volume of ethylene glycol for each sample

By using this equation, prediction of freezing point temperatures for mixtures with ethylene glycol volumes of 10 ml, 12 ml, 14 ml, 16 ml, and 18 ml are -51.595℃, -59.071℃, -66.547℃ and -81.499℃ respectively. From the data and graphs obtained and predicted above, it is found that higher ethylene glycol volume in a mixture will result the mixture in having a lower freezing point temperature. This is because the ethylene glycol disrupts hydrogen bonding when dissolved in water. Pure ethylene glycol freezes at about -12℃ but when mixed with water the mixture does not readily crystallized and therefore the freezing point of the mixture is depressed. Specifically, a mixture of 40% ethylene glycol and 60% of water are freeze at -45℃. This result from our experiment shows a good agreement with the data stated in [6]. This means that higher volume of ethylene glycol in a coolant mixture will result in the said mixture to be harder to be crystallized under low temperatures.

From the results and discussion obtained from both the specific heat capacity experiment and the freezing point temperature experiment, it is concluded that a moderate and specific amount of ethylene glycol is needed in a car radiator coolant mixture so that the coolant will not be easily crystallized while at the same time can absorb the most heat possible.

CONCLUSION AND RECOMMENDATIONS

In this study, the main objective is to study on how to a make a better coolant based on the specific heat capacity and freezing point of the mixture of ethylene glycol and ultrapure water with different ratios. However, the amount of ethylene glycol in the mixture plays a crucial role in affecting the production of the best car radiator coolant. The experiment result shows that the specific heat capacity of the mixture decreases as the amount of the volume of ethylene glycol that were used to mix with the ultrapure water increases. Same goes to the freezing point data that were obtained from DSC6000. The data shows that the freezing point temperature decreases when the volume of the ethylene glycol that were used in the experiment increases. In this experiment, it is found that 40% of ethylene glycol and 60% of ultrapure water are the best properties for a coolant to be used because the freezing point that were obtained is -45.97 ˚C. It is because only a moderate amount of ethylene glycol [7] is needed in a car coolant, so that the coolant will not crystallized easily.

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