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Alkaline Hydrolysis of Waste Pet Bottles for the Production of Terephthalic Acid and Ethylene Glycol

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ABSTRACT

The research studies the efficacy of alkaline hydrolysis of waste PET bottles to produce terephthalic acid and ethylene glycol. The process was carried out at a reaction temperature of (80-100)^{0}C, PET weight of (30-50) grams and reaction time of (30-90) minutes, involving depolymerization of PET bottles (using a mixture of ethanol, NaOH and de-ionized water), cooling, vacuum filtration, acidification and final filtration. The results revealed that the volume of terephthalic acid (TPA) weight and ethylene glycol produced attained climax at higher temperature showing that temperature and time are vital elements in recycling PET using chemical techniques (around temperature of 90-100^{0}C). Further analysis carried out for the determination of terephthalic acid and ethylene glycol using FTIR spectroscopy shows clear evidence supporting the molecular structure of terephthalic acid and ethylene glycol, particularly through the identification of characteristic functional groups such as hydroxyl (O-H) and carbon-oxygen (C-O) bonds. As well as the demonstration of the vital role of FTIR spectroscopy in evaluating the molecular structure of organic compounds. The study therefore recommended that future research should incorporate the use of HPLC where available for a more enhanced quantitative analysis to ascertain the purity and yield.

Keywords: Production, alkaline hydrolysis, terephthalic acid, ethylene glycol.

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1.INTRODUCTION

The need for plastics is steadily increasing every year due to it widespread use in various industries, including the packaging of food, automative components, film production, and synthetic manufacturing. Polyethylene terephthalate (PET) accounted for 8% of the 390.7 million tons of polymers manufactured globally in 2021(Jia , Gao, Yin, Qin, 2023).The majority of plastic items, such packaging materials, are created to be thrown away right away (Plastics Europe, 2020). The wide use of incinerators and landfilling are commonly utilized technologies in a linear polymer economy, which are major components of the existing PET plastic waste management system. PET plastic items are in high demand, and the European Union has a low recycling rate of 23%, which contributes to this scenario (Huang et al., 2022; Soares et al., 2022). Additionally, PET bottles, such plastic litter, also includes bottles, jars, wraps, and bags consisting of polyester and polyolefin. Even though PET lacks negative effects and explicit environmental threats, its enormous quantity in the waste stream and high resistance to biological and atmospheric agents lead to great environmental concerns once disposed of (Paszun & Spychaj, 1997). PET waste bottles have a tremendous negative impact on the ecosystem. It fragments into microplastics that pervade ecosystems and can find its way to enter the food process chain, as well as aesthetically pollute landscapes as well as rivers. There have been many health disorders in sea creatures as well as in human health that have been related to these microplastics. It's reported by The Guardian that a shocking million plastic drink bottles are bought every minute, in accordance with a report by Euromonitor International's Global Packaging Trends report (Laville & Taylor, 2017). Because plastic waste, highly prevalent PET, is a dominant environmental issue globally, solutions to such an issue have to be discovered. PET can be recycled by depolymerizing into its composing monomers, namely terephthalic acid (TPA) as well as ethylene glycol (EG), which serve as basic raw materials in PET production. By reducing waste containing plastic in landfills as well as in the environment, thereby reducing CO_2 emissions in the production of new PET, saving non-renewable energy, as well as production cost savings, such a PET recycling process can neutralize the damage to the ecosystem. Polymers can be categorized into monomers using a variety of techniques, such as chemical (Thiyagarajan et al., 2021; Ugduler et al., 2020), mechanical (Schyns & Shaver, 2021), physical (Laldinpuii et al., 2021), and biochemical/enzymatic (Muller et al., 2023).

Particularly, chemical recycling has clear benefits since it makes it possible to produce high-quality final products that satisfy modern standards. It is also a field that is always changing and undergoing innovation and advancement, with outstanding techniques such as hydrolysis, glycolysis, methanolysis, and aminolysis (Laldinpuii et al., 2021). Hydrolysis is thought regarded as one of the most efficient chemical recycling techniques for extending PET life cycle, decreasing the demand for non-renewable fuels as raw materials for PET production, and reducing plastic pollution that has adversely impacted on the surrounding (Liu et al., 2009; Yang et al., 2021a).

Moreover, hydrolysis-induced depolymerization produces ethylene glycol and terephthalic acid (Benyathiar et al., 2022; Jeya et al., 2022). Hydrolysis of PET can be grouped into three classes namely: alkaline, acidic, and neutral. Alkaline hydrolysis is one of the most promising of these for use in industrial recycling processes. This process has the capacity to produce high-quality ethylene glycol and terephthalic acid while also efficiently managing impurities(Barredo et al., 2023; Benyathiar et al., 2022). As a result of the numerous problems created by waste from plastics, there has been an increasing emphasis on the use of sustainable means of managing waste, with recycling having an upper hand.

This is because recycling provides many advantages, such as conservation of resources, saving energy and reduction in waste that gets to landfills and incinerators (Amundarain et al., 2024). Even with recycling, the recycling of plastic is still very low, which calls for more innovation (Hopwell et al., 2009).

The reaction of alkaline hydrolysis include the treatment of polyester together in an aqueous NaOH solution which ranges from 4% and 20% in weight (Aguado & Serrano, 1999), a review of literature shows that recent work on alkaline hydrolysis of PET used temperature of between 80˚C to about 220˚C(Abedsoltan,2023) using suitable reaction templates, a disodium salt of TPA is constituted and by acidification, the TPA is achieved from the samples as a precipitate. Notwithstanding, other studies done have recognized hydrolysis to be one of the outstanding chemical recycling methods for the recycling of PET but focus of most of these studies have been on clean PET products with known configuration when depend on the use of phase transfer catalysts (PTC) which is very costly and not easy to recover. Therefore, this present work aims to examine how efficient and viable the use of alkaline hydrolysis is in terms of sustainability in chemical recycling for the conversion of waste PET bottles to a high purity terephthalic acid and ethylene glycol.

2. MATERIALS AND METHODS

2.1. Sample Collection

PET bottles were obtained from Covenant University Cafeteria 2 and the chemical engineering building for this work on alkaline hydrolysis of waste PET bottles to produce terephthalic acid (TPA) and ethylene glycol (EG). Reagents used includes sodium hydroxide (NaOH) (98% purity obtained from J.T Baker), ethanol (99.8% purity, obtained from Fisher Specifics), de-ionized water, sulfuric acid (H_2SO_4) (specific gravity of 1.34, obtained from BDH laboratory supplies pool). The PET bottles were washed thoroughly to remove contaminants and cut into smaller pieces uniformly using grinder. The smaller pieces of PET bottles were weighed and kept in a container free of air before usage. A combination of literature review, experimental procedures as well as characterization of analysis was utilized.

2.2. Methods and Procedures

Minitab Statistical Software was utilized for designing experiment for the alkaline hydrolysis of waste PET bottles, which was aimed at producing terephthalic acid and ethylene glycol. With Minitab Statistical Software, alkaline hydrolysis of waste PET bottles can be optimized to produce terephthalic acid and ethylene glycol, identifying optimal conditions that maximize yields, reduce costs, and improve product quality through data analysis, process optimization, and predictive modeling. Alkaline hydrolysis of PET bottles process is shown in Figure 1, indicating steps taken for the experiment.

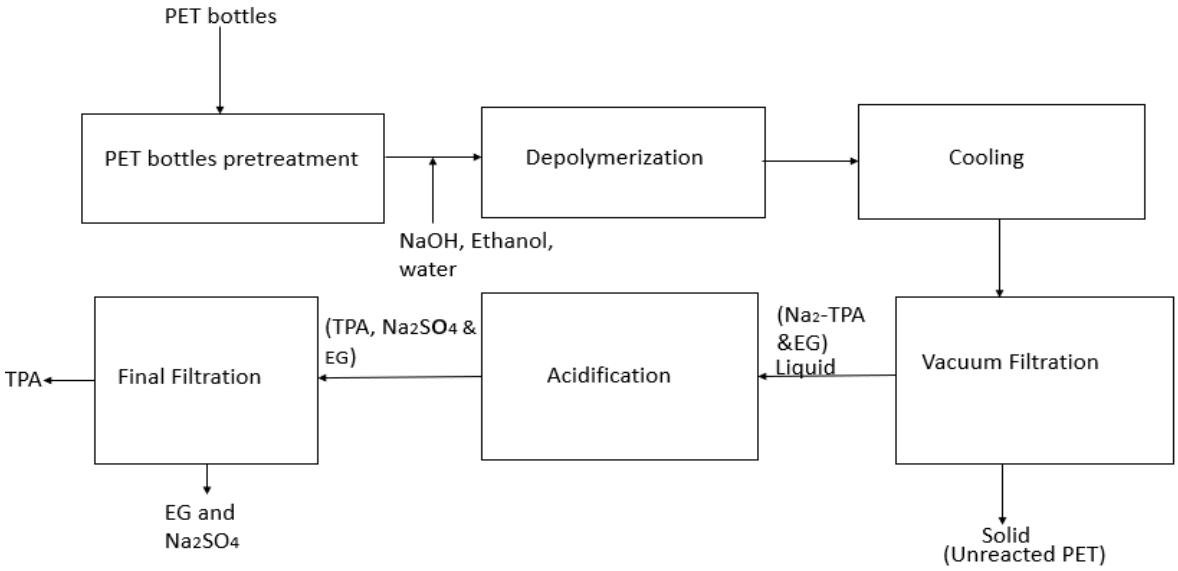

Figure 1. Flowchart of Process.

(a) (b) (c) (d)

(e) (f) (g)

Figure 2. Digital Images of Equipment Used.

3. RESULT AND DISCUSSION

This shows the results and interpretation from the study and their significances. Data obtained from the study will be presented in tables and graphs to give a graphical understanding of the analysis carried out. Statistical analysis is also carried out to provide a clearer understanding of findings from this work.

Table 1. Experimental Results from the Alkaline Hydrolysis Process.

Experimental Runs	Temperature	Time	Weight of PET	Weight of TPA produced (grams)	Volume of ethylene glycol produced (ml)
Run 1	80	60	30	1.6375	174
Run 2	90	90	30	2.0520	171
Run 3	80	90	40	1.3950	166
Run 4	90	60	40	2.4678	166
Run 5	100	30	40	2.2346	86
Run 6	90	30	50	3.4522	154
Run 7	90	60	40	0.8416	144
Run 8	90	60	40	3.6641	152
Run 9	90	90	50	7.3194	112
Run 10	100	90	40	6.5126	104
Run 11	100	60	50	2.4158	94
Run 12	80	60	50	2.3808	152
Run 13	100	60	30	3.1239	176
Run 14	80	30	40	3.2120	176
Run 15	90	30	30	3.3252	178

Source: Author's laboratory experiment, 2025

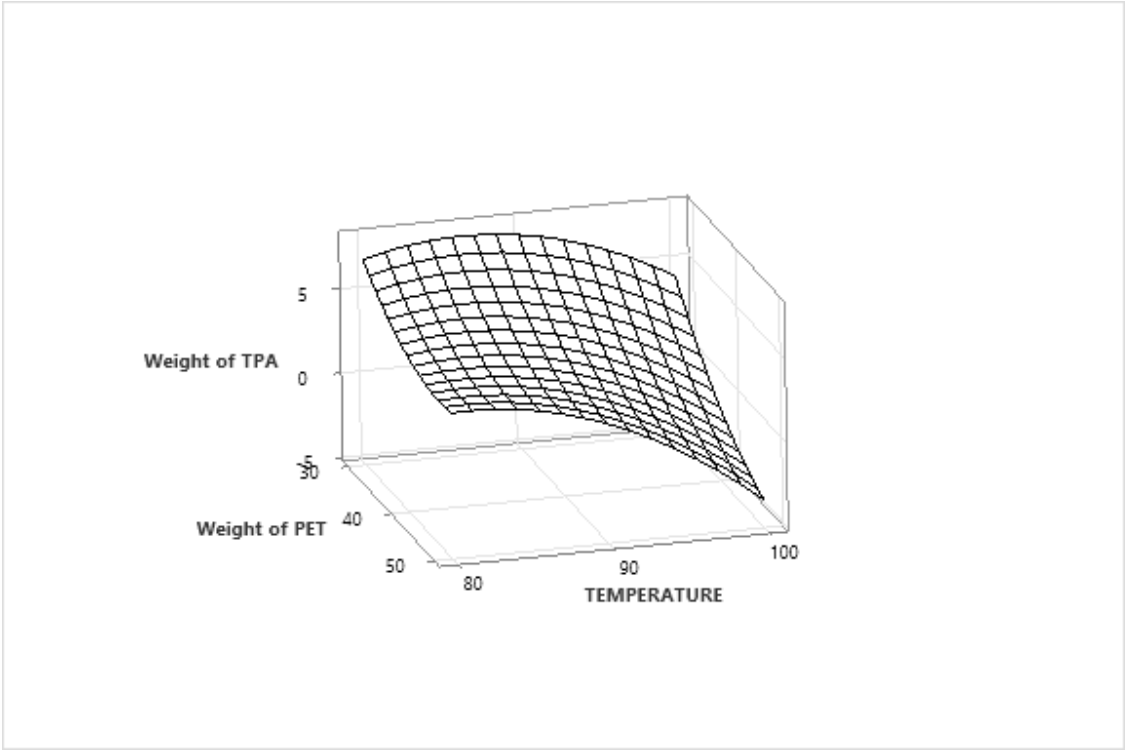

Figure 3. Surface Plot of TPA Weight Versus Temperature and PET Weight.

Figure 3 shows that as the amount of PET increases, the related weight of TPA decreases, which is an indication that TPA is probably being used up in the reaction. The surface graph shows that temperature has a positive influence on weight of TPA. Figure 3 also shows that around 50^0C, the higher weight of TPA is achieved, especially at lower weights of PET. With increasing temperature up to 100^0C, TPA weight decline significantly, especially with addition of more PET. This effect may mean that increased temperature increases the consumption effectiveness of TPA by speeding its incorporation into polymer chains when synthesized or by maximizing its breakdown or conversion in a degradation process.

The surface curvature emphasizes the non-linear dependence of the variables, with a steeper gradient in the direction of temperature than in the direction of PET weight. This implies that temperature plays a larger role in controlling TPA weight compared to PET weight. Conclusively, figure 3 indicates that temperature sensitivity of the process and in support of the hypothesis that TPA is degraded in polymerization or decomposed under higher conditions.

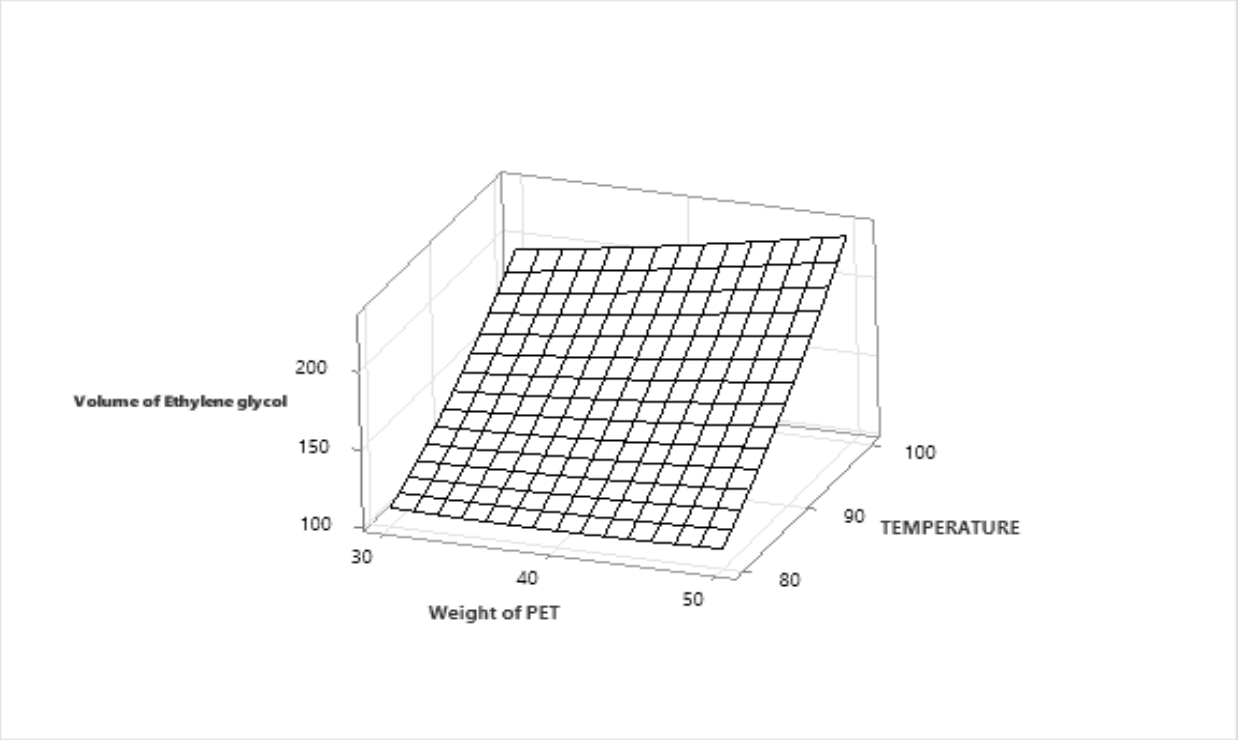

Figure 4. Surface Plot of Volume of Ethylene Glycol Versus Weight of PET and Temperature.

Figure 4 is an illustration of a surface plot showing the relationship between volume of ethylene glycol, temperature, and PET weight. The surface plot indicates that PET weight has a positive correlation with volume of ethylene glycol. The volume of ethylene glycol increases proportionately as PET weight increases. This means higher volumes of PET need proportionate amounts of more ethylene glycol either for effective polymerization or complete depolymerization, predicated on the type of reaction.

Temperature is also seen to perform a significant role in the system. As the temperature increases from about 80^0C to 100^0C, the volume of ethylene glycol increases. This indicates that elevated temperatures accelerate the process of reaction, maybe through accelerating reaction kinetics, enhancing molecular mobility, or optimizing ethylene glycol release. Although both independent variables have a bearing on the amount of ethylene glycol, the sensitivity of the system to PET weight seems to be slightly higher, suggesting that the system is slightly more sensitive to PET weight than to temperature difference.

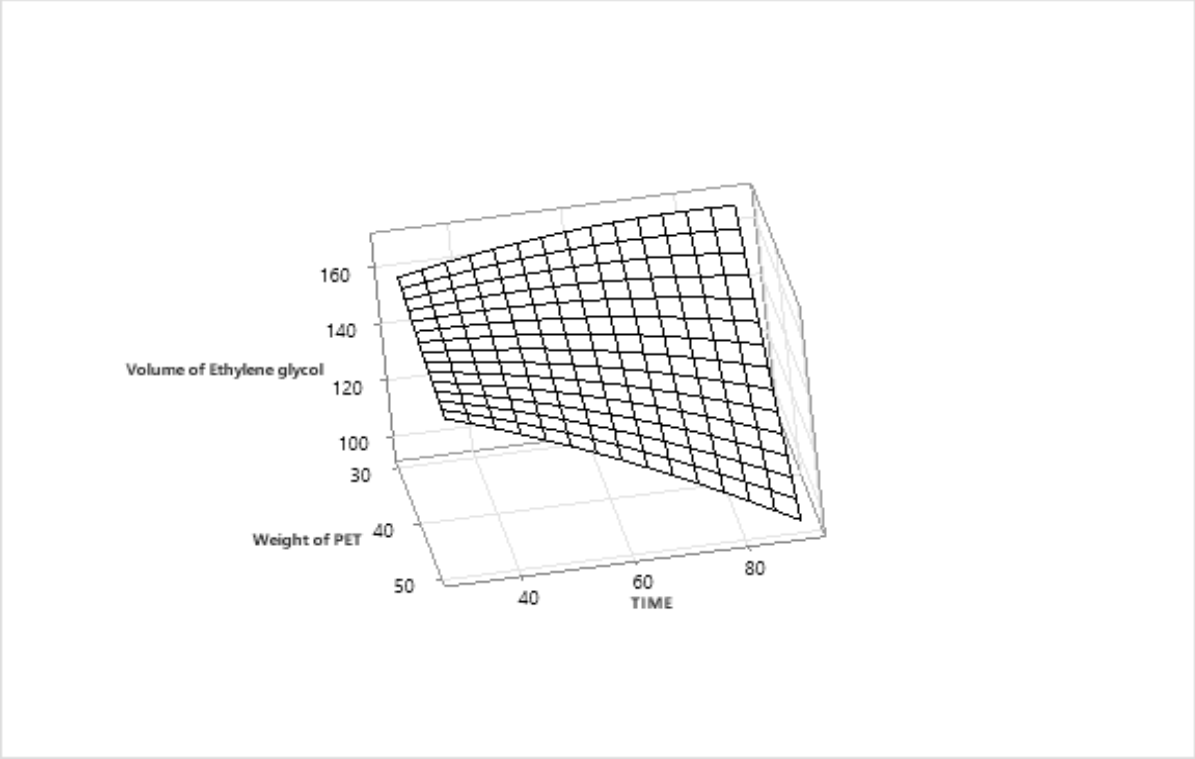

Figure 5. Surface Plot of Volume of Ethylene Glycol Versus Time, Weight of PET.

From Figure 5, it can be seen that the volume of ethylene glycol rises with PET weight regardless of the time interval. As far as reaction time is concerned, there is a reverse trend here, meaning that the longer the time, the lesser the ethylene glycol is formed, particularly when PET weight is also heavy. This reverse trend suggests that, as the reaction progresses, the ethylene glycol is increasingly depleted or utilized by the reaction matrix. This behavior is particularly typical for depolymerization reactions, wherein ethylene glycol persists in continuous reaction medium. In other words, reactions with higher PET do not just need additional ethylene glycol but also greater or more rapid consumption of glycol with increase of time. In summary, the decreasing rate in volume of ethylene glycol is significantly at higher weight of PET.

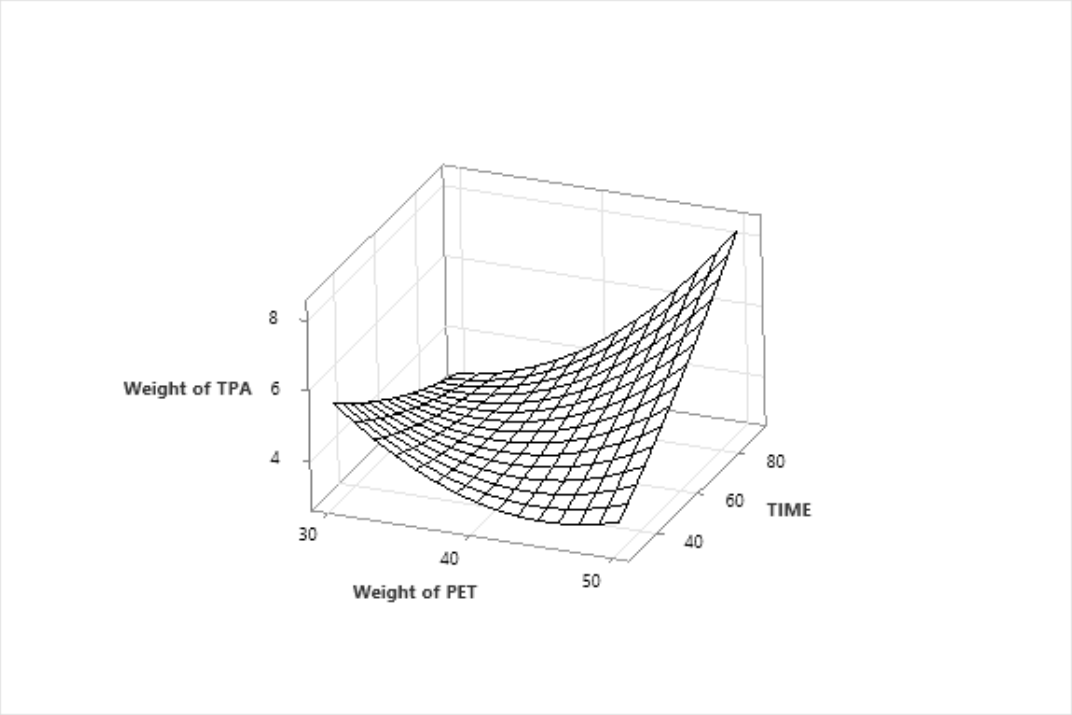

Figure 6. Surface Plot of Weight of TPA Versus Time and Weight of PET.

Figure 6 depicts the reaction time, weight of TPA and PET weight relationship with temperature constant at 90^0C. Figure 5 shows that the weight of formed terephthalic acid (TPA) also increases with increasing weight of PET and the reaction time being greater. This suggests that there is a positive relationship among these parameters within the experimental range. With smaller PET values and slower reaction times, the TPA weight is quite flat and low. But as each or both variables rise, particularly in combination with one another, there is a clear and steep increase in TPA yield. The greatest increase in TPA weight occurs at the top right-hand side of the plot, where both PET weight and time are maximized. The surface plot gives an important understanding of optimization techniques to produce TPA.

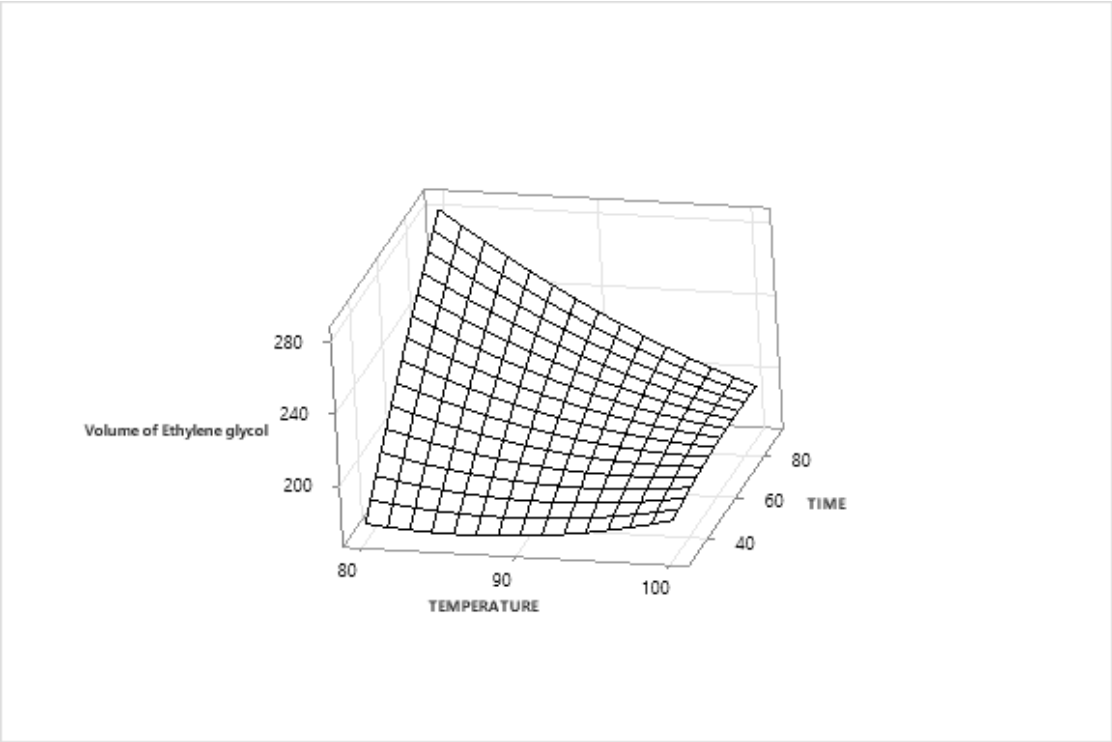

Figure 7. Surface Plot of Volume of Ethylene Glycol Versus Temperature and Time.

Figure 7 depicts a surface plot showing how the amount of ethylene glycol generated is a function of temperature and time. The graph indicant that the quantity of ethylene glycol changes non-linearly with temperature and time. On temperature effect, at temperatures below the range of 60-80^{0}C, ethylene glycol volume is quite small, thus, PET conversion is not complete. At higher temperature (80-100^{0}C), the volume of ethylene glycol increases maximally. This is an expected outcome since increasing temperatures will increase the rates of the reactions, speeding up the hydrolysis of PET to ethylene glycol. Optimum volumes are achieved at temperatures around 90-100^{0}C, suggesting an optimum temperature range for maximum ethylene glycol yields under current conditions. On the impact of time, figure 7 shows that at shorter time durations like 40 minutes, the volume of ethylene glycol is less, presumably because there is not enough time for the reaction to be complete. With longer time (60-80 minutes), the volume rises, indicating more conversion of PET to ethylene glycol. Regarding the interaction between time and temperature, increased temperature decreases the duration of time to reach maximum ethylene glycol volume. For example, with 100^{0}C, volume at maximum point reaches sooner than with low temperatures. This indicates that not only does temperature affect the reaction rate but also the time to reach maximum yields.

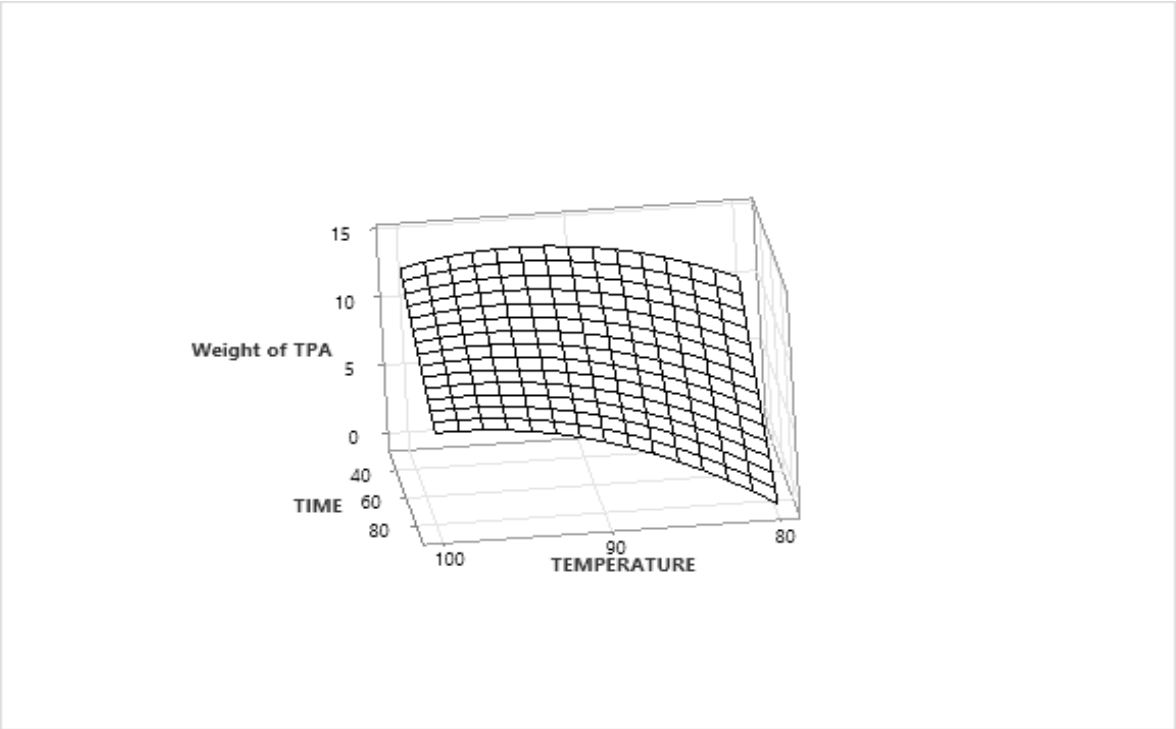

Figure 8. Surface Plot of Weight of TPA versus Time and Temperature.

The surface plot depicted in Figure 8 illustrates how TPA weight yield changes with respect to time and temperature. Figure 8 indicate that the production of TPA appears optimally when time and temperature is combined. On the impact of temperature on yield, the graph shows that at between 80-90^{0}C, was less, and at a temperature of 90-100^{0}C, the yield of TPA increased substantially. Time influence shows that between 50-60 minutes, the resulting TPA is less due to time for sufficient conversion. At moderate to long reaction times 70-85 minutes, the TPA yield increases significantly, which shows the relationship between time and temperature, showing that as temperature increases, less time is required to produce significant yield of TPA.

3.1. Analysis

The samples were synthesized and characterized using FTIR analysis, confirming the presence of key functional groups through characteristic peaks in the spectra. The results demonstrate the successful production of these compounds.

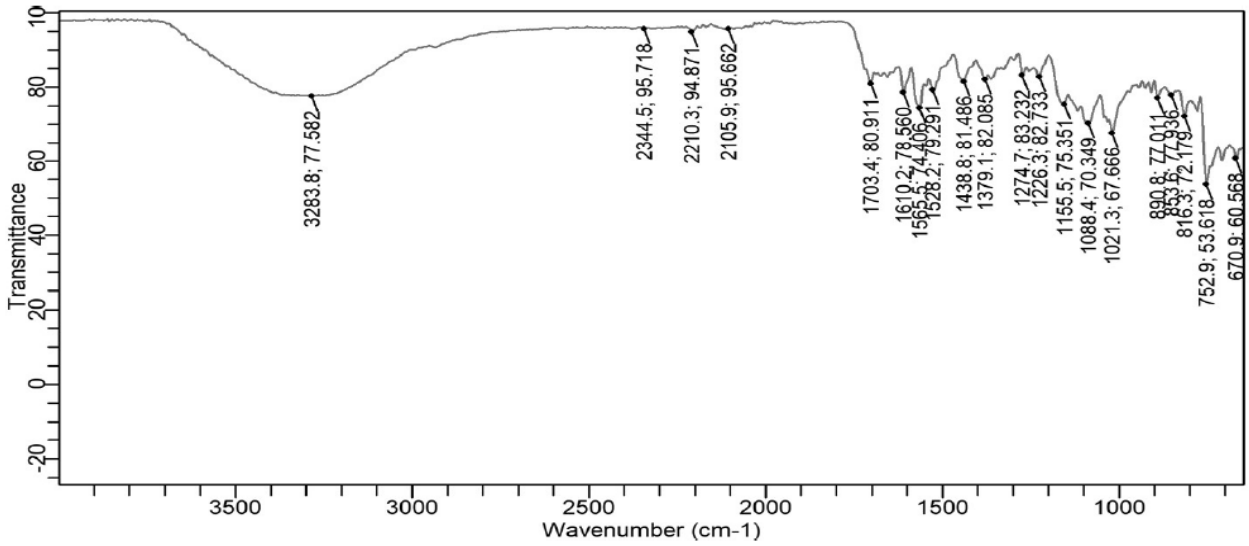

Figure 9. FTIR Analysis Result for Ethylene Glycol.

Analysis on ethylene glycol gotten in run 1 was carried out in the mid-infrared zone from 4000 to 650cm^{-1}: a characteristic range for organic compounds. This range is particularly important for determining the molecular vibrations of various functional groups in organic chemistry. The zone of the mid-infrared is specifically potent in the identification of bonds that involve hydrogen, oxygen, and carbon, which are common in the structure of most organic molecules.

In this analysis, a peak range of 3300-3600cm^{-1} was expected due to the O-H stretched, showing that the alcohol groups were indeed present in ethylene glycol. Not only do these peaks suggest the presence of hydroxyl groups, the distinctiveness of these peaks also points to the fact that there is considerable hydrogen bonding in this compound, affecting some of the physical properties of the compound like boiling point or viscous nature. This attribute is a significant consideration when ethylene glycol is applied as a solvent or antifreeze fluid in several formulations, as this renders it much more useful in various applications.

These peaks mark the presence of ether or alcohol functional groups, and their presence is significant in the understanding of how ethylene glycol will behave in a reaction. The C-O bonds that were detected show that the molecular environment has a certain degree of reactivity and stability in industrial procedures such as the production of plastics and resins, which is relevant to the molecular environment.

In Figure 8, a further peak was noticed in the zone of 1400-1500cm^{-1} which is indicative of the C-H bending vibrations, supporting the identification of ethylene glycol in the samples assessed. The presence of these bending vibrations denote that aliphatic chains are present in the molecule, which enhances its stability and reactivity. In addition, these peaks noticed in Figure 9 shows very important information regarding the molecular patterns and symmetry that are vital in the understanding of the interaction of ethylene glycol with other chemical species in different environments. The range ascribed to each intensity value shows the concentration of reactive groups at hand, high values denote excess of these functional groups.

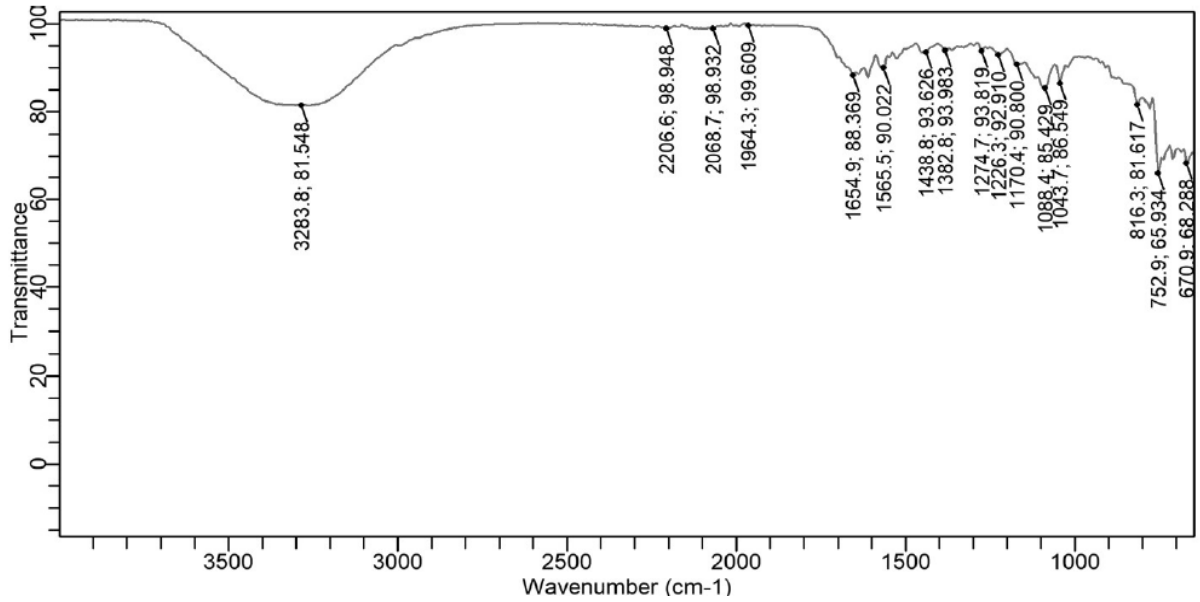

Figure 10. FTIR Analysis Result for Ethylene Glycol.

Analysis on ethylene glycol gotten from run 13 was carried out in the mid-infrared region from 4000 to 650cm^{-1}, which is within the range of organic compounds. Around 1043.65cm^{-1} peaks are significant since they pertain to C-O stretching vibrations which are typical of alcohols. These peaks support the presence of carbon-oxygen bonds in ethylene glycol because such bonds are important for it to be a diol.

Ethylene glycol's value of (86.55 and 85.43) shows that these functional groups have a strong presence and thus reflect the structure of the compound. The peaks at 1382.84cm^{-1} and 1438.75cm^{-1} are probably associated with C-H bending vibes which tend to occur in alkaline derivatives. These peaks confirm the classification of ethylene glycol as an aliphatic alcohol. The value of these peaks (93.98 and 93.63) shown in Figure 9 strengthen the claim that these bonds are present in abundant quantities. The peak value of 3283.78 cm^{-1} is striking because it represents O-H stretching vibrations, which are usually associated with hydroxyl groups.

Similarly, the observed peak in figure 10 shows the presence of hydroxyl functional groups in ethylene glycol, which, as expected, play a significant role in its solubility in water and influence various physical properties. The peak intensity of (81.55) points to a substantial concentration of these hydroxyl groups. Meanwhile, the higher wavenumber peaks observed at 1964.31cm^{-1} and 2068.67cm^{-1} are probably associated with overtones or combination bands arising from fundamental molecular vibrations-a phenomenon commonly encountered in organic compounds. Furthermore, the intensity values observed for these peaks, 99.61 and 98.93, emphasize their importance within the overall spectral profile. The FTIR analysis gives clear evidence supporting the molecular structure of ethylene glycol, particularly through the identification of attribute functional groups such as hydroxyl (O-H) and carbon-oxygen (C-O) bonds.

The pronounced peaks linked to C-O and O-H stretching vibrations confirm the compound's classification as an alcohol, which correlates well with its practical applications as a solvent and antifreeze agent. This assessment does not only authenticate the sample but also establishes a solid basis for subsequent research or potential applications involving ethylene glycol in a range of chemical contexts. The detailed focus on these spectral features highlights the value of FTIR spectroscopy in evaluation of the molecular composition of organic compounds.

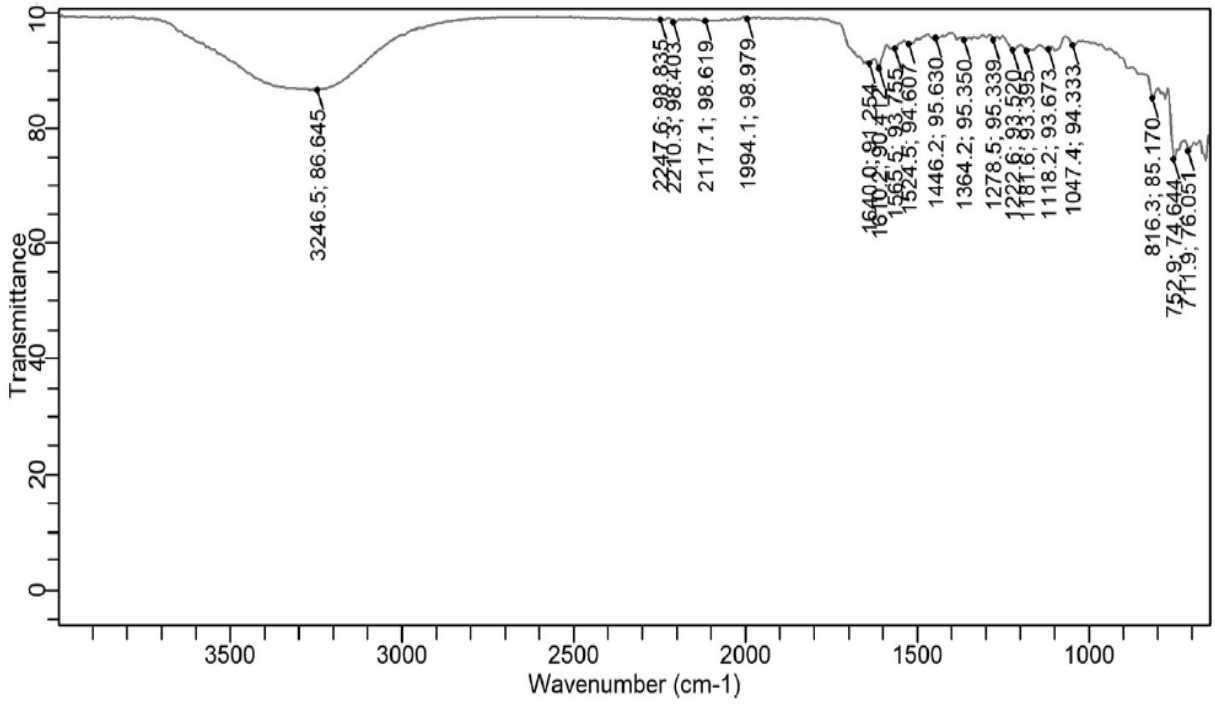

Figure 11. FTIR Analysis Result for Ethylene Glycol.

Analysis was done on ethylene glycol gotten from run 15. In Figure 11, the earlier peak at 711.92cm^{-1} and 752.92cm^{-1} probably point toward C-H bending vibrations, possibly with some other interactions of the molecule, close to peak 1047.38cm^{-1} and 1118.20cm^{-1} which are suggestive of C-O stretching vibrations, for which alcohols are known for. The peaks shown in figure 4.9 are further indications of the presence of carbon-oxygen bonds in ethylene glycol which are part of the important elements in a diol. Figure 11 also shows a substantive value of 94.33 and 93.67 showing a potent presence of the functional groups. Similarly, figure 11 shows a peak of 1364.21cm^{-1} and 1446.21cm^{-1}, which is an indication of C-H bending vibrations, showing that the sample is ethylene glycol.

The absorption peak at 3246.51cm^{-1} is especially significant, as it corresponds to O-H stretching vibrations; a definitive indicator of hydroxyl groups within the molecular structure. The observation affirms the presence of hydroxyl functionalities in ethylene glycol, which accounts for its pronounced solubility in water and influences various physical properties. The intensity of this peak (86.65) further underscores a substantial concentration of hydroxyl groups present. Additionally, the peaks observed at 1994.13cm^{-1} and 2117.13cm^{-1}, both with notable intensities (98.98 and 98.62, respectively), are likely attributable to overtone or combination bands arising from fundamental vibrational modes. The prominence of these features in the spectral profile offers further insight into the molecular characteristics and vibrational dynamics of ethylene glycol.

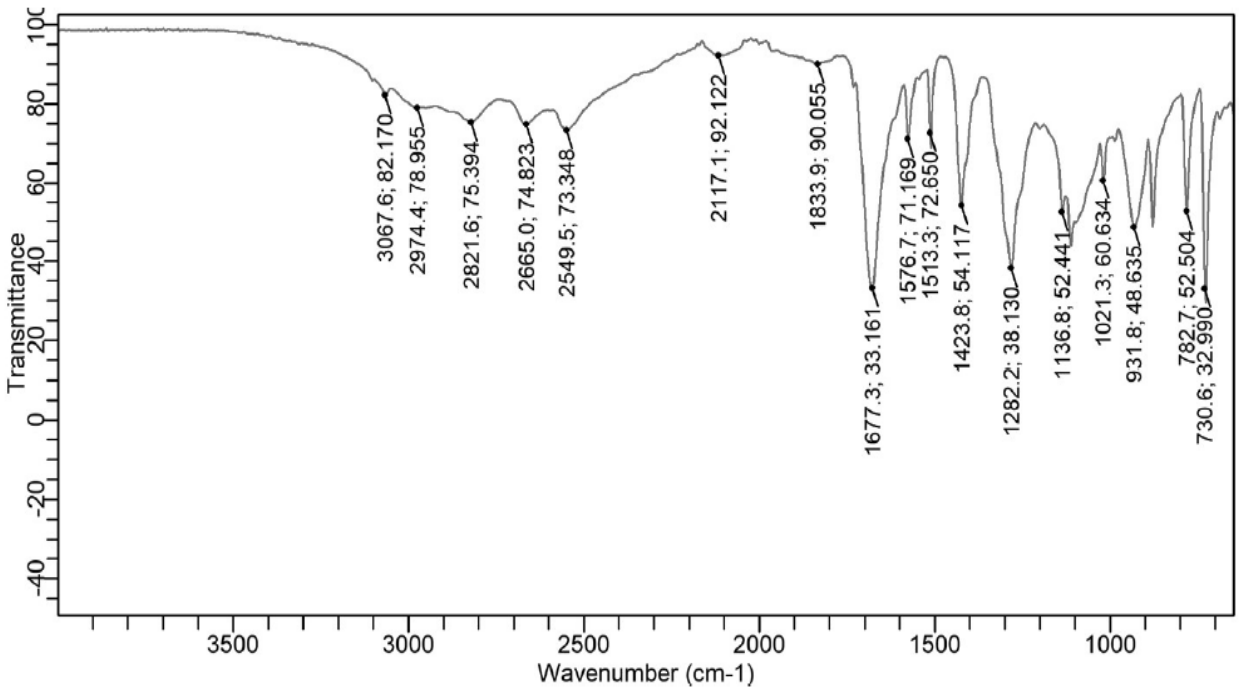

Figure 12. FTIR Analysis Result for Terephthalic Acid.

FTIR analysis was done on the sample gotten in run 9 to confirm the presence of terephthalic acid in the sample. The initial peaks noticed at lower wavenumbers in Figure 12, specifically at 726.83cm^{-1} and 782.74cm^{-1}, is an indication of out-of-plane C-H bending vibrations, which are characteristics of aromatic compounds. This observation corroborates the presence of a benzene ring within the terephthalic acid molecule, confirming its aromatic character. Additionally, in C-O stretching vibrations, a significant feature of carboxylic acid groups. The identification of these peaks substantiates the existence of carboxyl functional groups(-COOH) in terephthalic acid, which are integral to its chemical behavior. The pronounced peak at 1509.57cm^{-1} conforms to C=C stretching vibrations within the aromatic ring, serving as a distinct marker of aromaticity.

Again, the peak seen at 76.26 reveals the abundance of hydroxyl groups, which are base to acid solubility and reactivity. The observable values of (87.06 and 91.22) recorded at this point show how significant they are in the general spectral profile, providing useful understanding of how hydroxyl groups behave within the compound.

The combined assessment using FTIR analysis supports the structural identity of terephthalic acid, its main functional groups, including carboxylic acid moieties and aromatic rings. Strong absorption bands corresponding to C=O and O=H stretching further shows the functional character that are necessary to the compound's applications, especially in producing polyester and other materials. This logical method not only confirms the sample's identity but also shows a solid foundation for other works or practical applications involving terephthalic acid. The detailed analysis of these spectral features demonstrates the important role of FTIR spectroscopy in assessing the molecular structure of organic compounds.

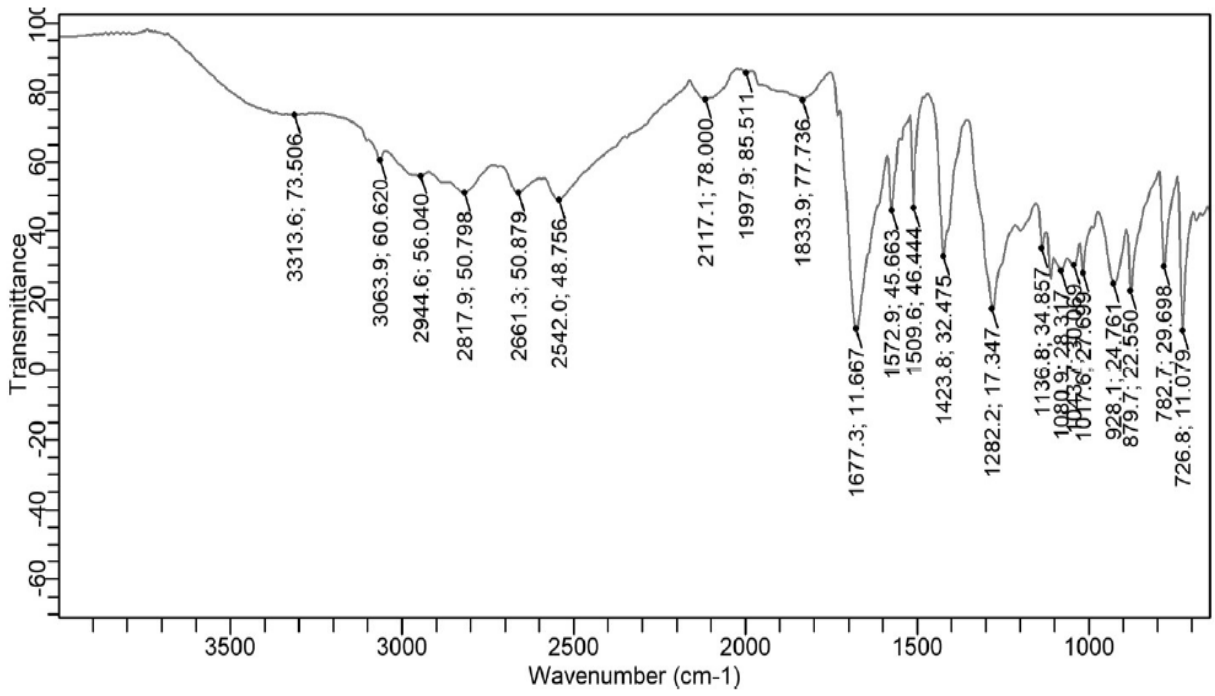

Figure 13. FTIR Analysis Result for Terephthalic Acid.

Analysis was done on the sample gotten from run 10. As displayed in Figure 13, the absorption peaks observed at lower wavenumbers, specifically at 730.56cm^{-1} and 782.74cm^{-1}, are attributes of out-of-plane C-H bending vibrations found in aromatic compounds. This observation supports the abundance of a benzene ring structure within terephthalic acid. In addition, prominent peaks near 1021.29cm^{-1} and 1136.84cm^{-1} conform to C-O stretching vibrations, indicative of carboxylic acid functional groups. The detection of these peaks gives clear proof for the existence of -COOH groups, which play significant role in the reactivity and chemical behavior of terephthalic acid. Furthermore, the peak at 1513.30cm^{-1} is credited to C=C stretching within the aromatic ring, highlighting the aromatic nature of the molecule. The strong intensity recorded for this peak (72.65) further underscores the prominence of these aromatic bonds in the compounds structure.

Again, the peak depicted at 1833.85cm^{-1} shows O-H stretching vibrations, which strongly indicate the presence of hydroxyl groups within the carboxylic acid functional group of terephthalic acid. The intensity shown in the graph (90.05) points to a huge concentration of hydroxyl groups, which, in turn, contribute majorly in the compound's solubility and chemical reactivity.

Additionally, the spectral elements in the higher wavenumber area, at 2549.50cm^{-1} and 2665.05cm^{-1}, can be linked to overtone or combination bands associated with O-H stretching. The measured intensities for these peaks (73.35 and 74.82) further underscore their importance, offering deeper insight into the vibrational behavior of the hydroxyl category shown in the molecule.

The results in this study show that FTIR analysis gives clear proof of the structural character of terephthalic acid, as shown by the presence of characteristic functional groups such as carboxylic acid and aromatic rings. Specifically, the diverse and noticeable concentration peaks correspond to C=O and O=H stretching vibrations point directly to the functional attribute that marks the compound and its importance in polyester production and related applications. Ultimately, the detailed assessment of these spectral features signifies the vital role of FTIR spectroscopy in examining the molecular properties of organic compounds.

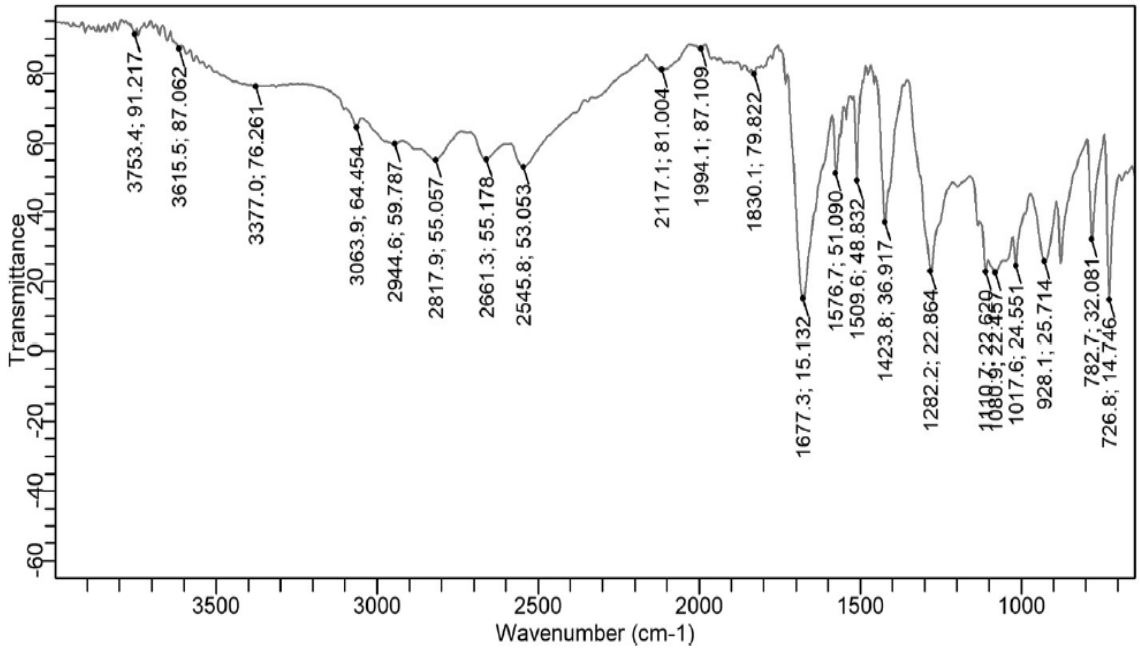

Figure 14. FTIR Analysis Result for Terephthalic Acid.

Analysis from run 11 shown in Figure 14 indicate an initial absorption peak at lower wavenumbers 726.83cm^{-1} and 782.74cm^{-1} which is an indication of out-of-plane C-H bending vibrations. These features are characteristics of aromatic compounds, supporting the presence of a benzene ring within the terephthalic acid molecule. Meanwhile, the peaks near 1017.56cm^{-1} and 1043.65cm^{-1} correspond to C-O stretching vibrations, which are typical markers of carboxylic acid groups. This affirms the presence of the carboxyl (-COOH) functional category in terephthalic acid, which are crucial for its chemical reactivity. The absorption at 1509.57cm^{-1} is attributed to C=C stretching within the aromatic ring, further ascertaining the compound's aromatic nature.

The data in figure 14 demonstrates the aromatic nature of the compound, with a notable signal (intensity 46.44) indicating a substantial presence of aromatic bonds. The peak observed at 1833.85cm^{-1} conforms to O-H stretching vibrations, characteristics of hydroxyl groups within the carboxylic acid functional group. The considerable intensity at this point (77.74) suggests a significant concentration of hydroxyl groups, which is consistent with the compound's known solubility and reactivity.

Additionally, the peaks detected at higher wavenumbers specifically at 2944.60cm^{-1} and 3063.87cm^{-1} can be credited to C-H stretching vibrations. Their intensities (56.04 and 60.62, respectively) further support their importance in the overall spectrum. Collectively, these FTIR spectral features confirm the structural identity of terephthalic acid by highlighting its key functional groups, namely the aromatic rings and carboxylic acid moieties.

The observable peaks corresponding to C=O and O=H stretching show the diverse functional groups present in the compound, which are vital for their use in synthesizing polyesters and related materials. This analysis agrees with the identity of the sample as terephthalic acid and establishes a reliable basis for further research or practical applications. The careful observation of these spectral features shows how efficient FTIR spectroscopy can be in examining the molecular structure of organic compounds.

4. CONCLUSION

This study shows the efficacy of alkaline hydrolysis of waste PET bottles used for producing the forms of terephthalic acid and ethylene glycol. A wide literature review was conducted out to ascertain studies that have been conducted in the use of terephthalic acid and ethylene glycol for various purposes. The study involved the collections of waste PET bottles from different units within the university environments. These PET bottles were cut into tiny pieces which were weighed and kept in a container free of air before using them. Several stages of laboratory experiments were conducted using reagents like sodium hydroxide, ethanol, de-ionized water and sulfuric acid.

Minitab statistical software was used to carry out the design of experiment for the alkaline hydrolysis of waste PET bottles, which was aimed at producing terephthalic acid and ethylene glycol, providing valuable guidance throughout the process. Three numerical independent variables that were used include temperature, time, weight of PET. The temperature range was between 80°C and 100°C. The time range was between 30 to 90 minutes, and the range of weight of PET used was between 30grams to 50grams. The total number of experimental runs was 15 in total. This study looked at wider coverage by looking at alkaline concentration, reaction temperature as well as time duration to determine maximum recovery of terephthalic acid and ethylene glycol. While carrying out the various experiments in the laboratory, several safety measures were adhered to such as water: ethanol was poured carefully into the three necked round bottom flask to avoid spilling, wearing of lab coats and gloves throughout the experiment, monitoring of experimental runs closely to avoid overheating as well as caution in handling reagents. Samples derived from the experimental runs were taken to the laboratory for the determination of the presence of terephthalic acid and ethylene glycol. Results obtained from the laboratory suggested different wavelengths at varying intensities. FTIR spectroscopy was used for the determination of terephthalic acid and ethylene glycol in the samples. The careful observation of these spectral features demonstrated in the samples shows the effectiveness of FTIR spectroscopy in assessing the molecular structure of organic compounds.

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