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Study of the Process of Polyethylene Terephthalate Destruction

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Particular attention in the development of plastic waste recycling technologies is paid to chemical methods of recycling solid household plastic waste, in particular PET waste, as one of the most common. Chemical methods for recycling polyethylene terephthalate make it possible to obtain a whole range of compounds that can be reused both for the production of PET itself and for the synthesis of new oligomeric or polymer products. One of the most promising methods for chemical recycling of polyethylene terephthalate waste is the aminolysis process due to the wide variety of PET degradation products obtained.

During the study, the reaction of aminolytic destruction of crushed PET waste with a mixture of amino alcohols was carried out in different ratios 1:3.5:5 and 1:2.5:4, respectively, for PET:MEA:TEA. The choice of these ratios of amino alcohols is due to the need for a sufficient amount of amino alcohols for the decomposition of PET particles and more economically advantageous conditions due to a decrease in the amount of amino alcohols , relative to literature data, where a ratio of 1 to 10 was used, respectively, for PET to MEA (or TEA).

The target product N, N'-bis(2-hydroxyethyl) terephthaldiamide during the destruction process produces ethylene glycol as a by-product, which can also be further isolated and used. In addition, it is worth noting the presence of 2,2'-(1,4-phenylene)-bis(2-oxazoline), which was discovered when analyzing the PET destruction product using gas chromatography-mass spectrometry at an analysis temperature of 400°C. The presence of this compound is due to the fact that upon rapid heating to high temperatures (400°C), the target degradation product (N, N'-bis (2-hydroxyethyl) terephthaldiamide) splits off two water molecules with the closure of two oxazoline rings.

The destruction reaction correlates with data from other studies that were discussed in the first chapter of this work. The main differences in this case are the absence of process catalysts and the use of a mixture of amino alcohols in smaller quantities.

Figures 1 and 2 show the dependence of the yield of the target degradation product on conditions such as temperatures of 145, 155 and 165°C and reaction time from 30 to 240 minutes. The reaction was carried out under convective heating, atmospheric pressure and without the use of catalysts, which is justified by the reduction in energy costs for carrying out this reaction under the given conditions.

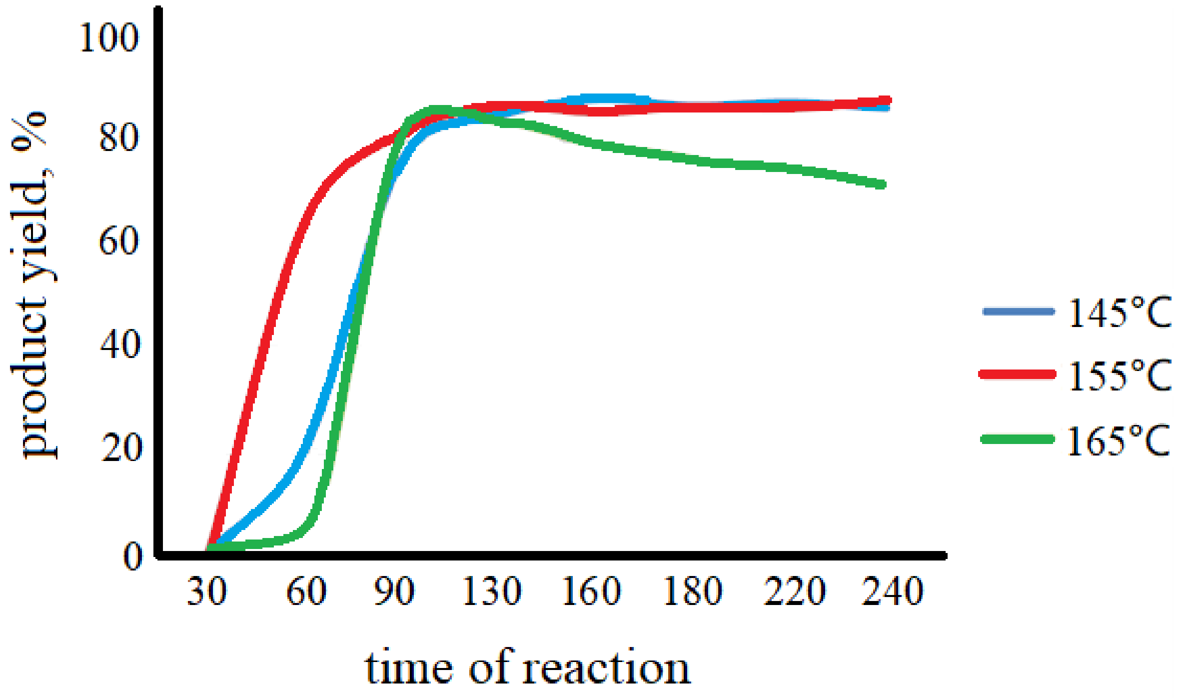

Fig. 1 – Kinetics of PET destruction at the ratio of components PET:MEA:TEA - 1:3.5:5 at different temperatures

As can be seen from Figure 1, the maximum product yield for all three temperatures is achieved in the time range from 95 to 125 minutes. For a given reaction time, the product yield is between 80 and 85 percent. It is also possible to reverse the slight increase in product yield at 145°C with longer reaction times of more than 125 minutes. In this case, the increase in product yield is from 2% to 3%.

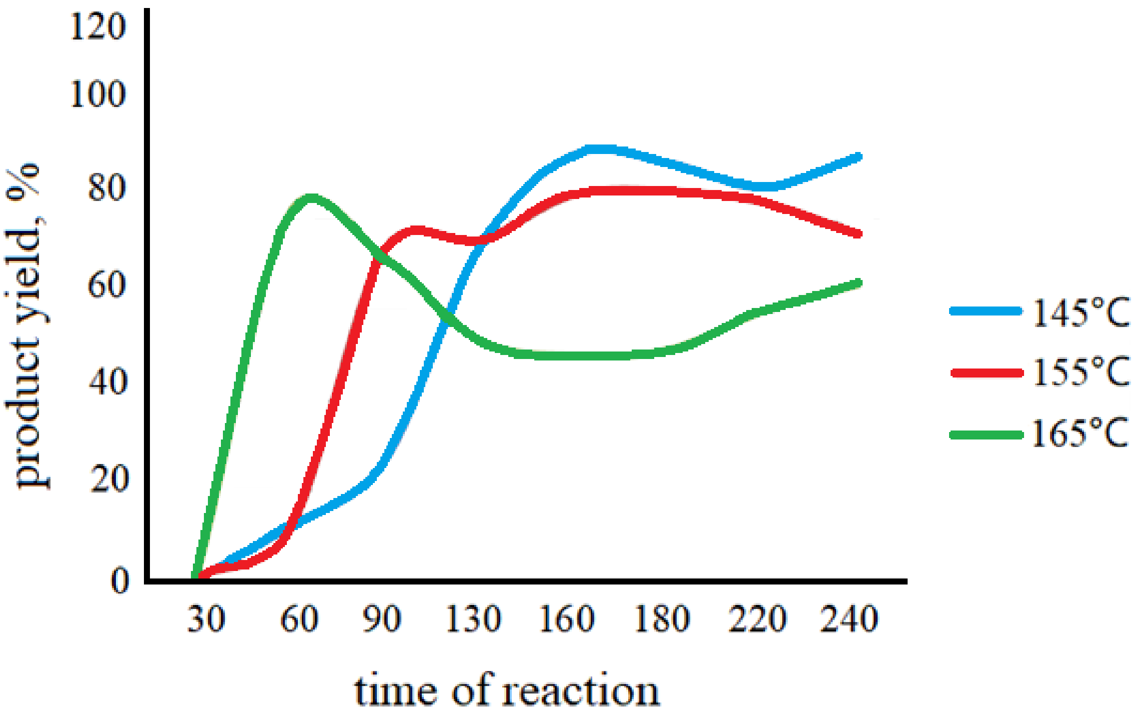

Fig. 2– Kinetics of PET destruction at the ratio of components PET :M EA:TEA - 1:2.5:4 at different temperatures

It is worth paying attention to the curve corresponding to 165°C: after 125 minutes of reaction, the yield of the product begins to decrease, due to the partial evaporation of the mixture of amino alcohols , especially the evaporation of MEA (T_{bp}=170°C). In view of this, carrying out this reaction at a given temperature is impractical.

With a component ratio of 1:3:4, a different picture is observed. In this case, the maximum product yield of 89-90% is achieved with a longer reaction time - more than 150 minutes. In general, with this ratio, a lower product yield is achieved due to the smaller amount of amino alcohol mixture, which at a high temperature of 165°C and a process duration of more than 65 minutes is also due to the evaporation of amino alcohols and their disadvantages for the decomposition of PET particles.

After aminolytic destruction of PET, the products were purified by double recrystallization from hot water. The pure degradation product (N, N'-bis(2-hydroxyethyl) terephthaldiamide) is a white crystalline powder with a melting point of 226°C (Fig. 3).

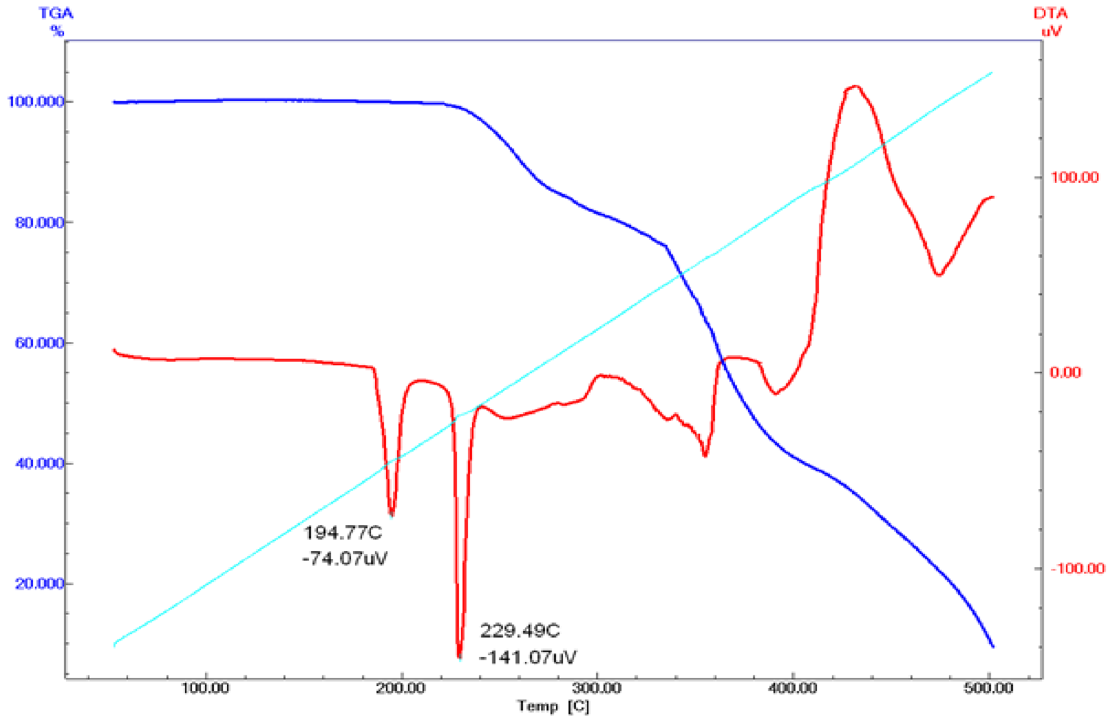

Fig. 3 – Differential thermal analysis data

The solubility of the destruction product was observed only in hot water from 90 to 95°C, dimethylformamide and dimethyl sulfoxide.

To confirm the structure of the resulting PET destruction product, the IR spectrum analysis method was used. Figure 4 shows the IR spectrum of the resulting PET degradation product.

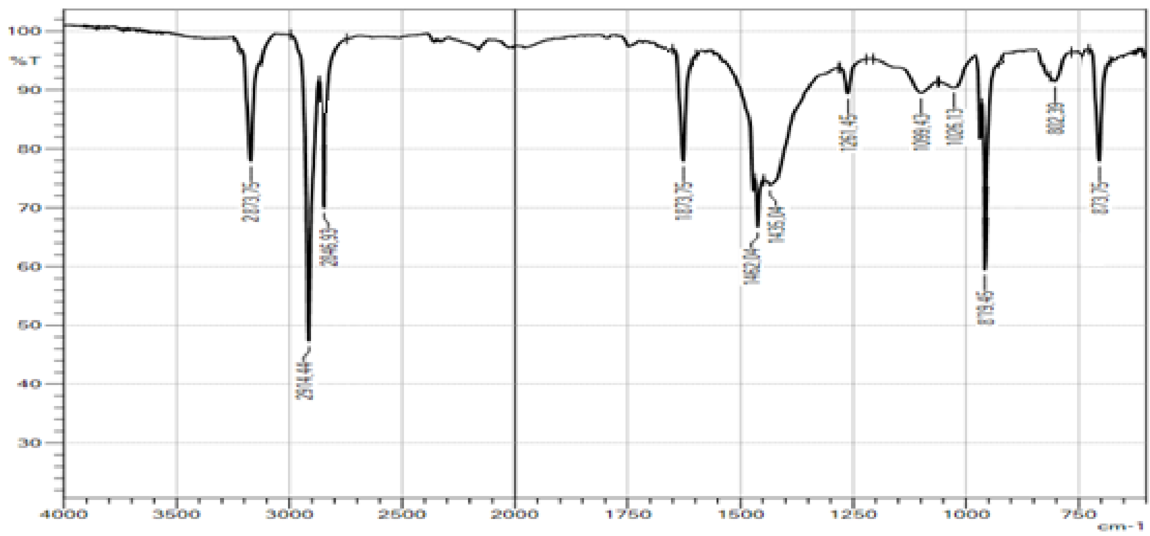

Fig. 4 – IR spectrum of PET destruction product

Obtained IR spectrum data correlate with data from a literature review on PET aminolysis. However, in this case, milder conditions, microwave radiation, without the use of catalysts were used to obtain N, N'-bis(2-hydroxyethyl) terephthaldiamide.

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