The Austrian Journal of Technical and Natural Sciences, No 9–10
ISSN 2310-5607

PREMIER Publishing
ppublishing.org

DOI:10.29013/AJT-25-9.10-51-57

DETERMINATION OF THERMAL STABILITY OF POLYMERIC MATERIALS BASED ON RECYCLED POLYETHYLENE

Safarova Matluba Alimkulovna [1], ***Shakhnoza Mamatova Berdikobilovna*** [1], ***Davranova Guzal Turdievna*** [1], ***Kurbanov Mingnikul Jumagulovich*** [1], ***Dilnoza Shavkatova*** [1]

[1] Karshi State University

Cite: *Safarova M.A., Shakhnoza M.B., Davranova G.T., Kurbanov M.J., Dilnoza Sh. (2025). Determination of thermal stability of polymeric materials based on recycled polyethylene. Austrian Journal of Technical and Natural Sciences 2025, No 9–10.* https://doi.org/10.29013/AJT-25-9.10-51-57

Abstract

The purpose of this article is to obtain lightfast, resistant to oxidation, aggressive environments and heat-resistant polymeric materials based on low-pressure polyethylene waste by adding chemical binders and fillers. The analysis of heat resistance of polymeric materials modified with chemical binders and fillers is carried out.

Keywords: *polyethylene, polypropylene, oligomer, sulfur, melamine, sodium acetate, extruder, derivatogram, thermogravimetry*

Introduction

Today, the world's population is growing exponentially. This growth leads to the fact that humanity's need for modern equipment and materials is growing every day. As a result, the globalization of large cities, the development of production and industry lead to the formation of a large amount of industrial harmful gases, solid and household waste. This will lead to serious environmental problems for humanity and the environment in the future. Currently, the use of disposable polyethylene packaging is growing rapidly. The disposal of these wastes and their economic use have become one of the main problems of our time. In the field of recycling polyethylene packaging waste, a number of authors describe numerous recycling methods in the scientific works of a number of authors (Mamatova Sh.B., Qurbonov M. J., Safarova M. A., 2024; Mamatova Sh.B., Kurbanov M.Zh., 2022; Mamatova Sh.B., Kurbanóv M. J., Safarova M. A., Izbasarova G., 2024; Mamatova, Sh.B., Kurbanov, M.Zh., 2023).

It is known that polyethylene waste, although withdrawn from consumption, loses its original properties, but these materials are not considered obsolete. The efficiency of recycling of waste from these polymer products depends not only on the technology of their processing, but also on the quality of the material involved in processing, its homogeneity, as well as the quantitative content of contaminating mechanical and organic impurities. During operation, plastics lose elasticity and become brittle under the influence of heat, moisture, stress, radiation (α, β and γ radiation), as well as oxygen in the air. As a result, the mechanical and electrical properties of products made of polymeric materials deteriorate. In particular, the effect of temperature adversely affects most of the physical and mechanical properties of polymer materials. Lowering the temperature increases the brittleness of most polymer materials, while heating reduces properties such as coefficient of linear expansion and viscosity. High temperatures also lead to changes in the mechanical properties of polymeric materials (tensile, bending, compressive strength, etc.) (Mamatova Sh.B., Qurbonov M. J., 2023; Mamatova Sh., Safarova M., Davronova G., Raxmatova G., Makhmayorov J., Abdullayev B., Kurbanov M. 2024; Mamatova Sh.B., Qurbanov M. J., To ʻrayeva M., 2024).

Research methods

For the study, the waste of low-density polyethylene of PY-456 grade produced by the Shurtan Gas Chemical Complex, which had served its service life, was sorted, cleaned of mechanical impurities, washed repeatedly and the purified product was dried in a special dryer. After that, the purified product was crushed in a special device. A certain amount of the resulting product was taken and placed in the extruder. Also, to obtain a heat-resistant polymer material, a certain amount of sodium acetate, sulfur, melamine and polypropylene oligomer was added to the crushed secondary polyethylene. To obtain a mixed polymer mass, the extruder operating mode was set at 60 rpm and the temperature was 115–140^{0}C. To form a homogeneous mixture in the extruder, the product was passed through the extruder 2 times.The resulting hot mixture was cooled and placed in a granulator. During the granulation process, the hot mixture was transferred to the forming head. Passing through the head, the mass was continuously squeezed out in the form of a wire, cooled and cut into granules with a special knife. The size of the samples was 3–5 mm. These granules served as the main raw material for further research.

All studies of polymer materials obtained from secondary polyethylene waste were carried out in accordance with the requirements of the State Standard for Polymer Materials. In particular, the data of thermogravimetric analysis of the obtained polymer materials were carried out in accordance with the requirements of GOST-12423. Samples for thermogravimetric analysis were identified by the difference between the initial temperature and the rate of decomposition.

The results of a thermogravimetric study of polymeric materials based on recycled polyethylene were calculated on the basis of the rate of mass loss of the samples taken for the experiment according to the following formula:

$$\upsilon m = \Delta m / \Delta \tau$$

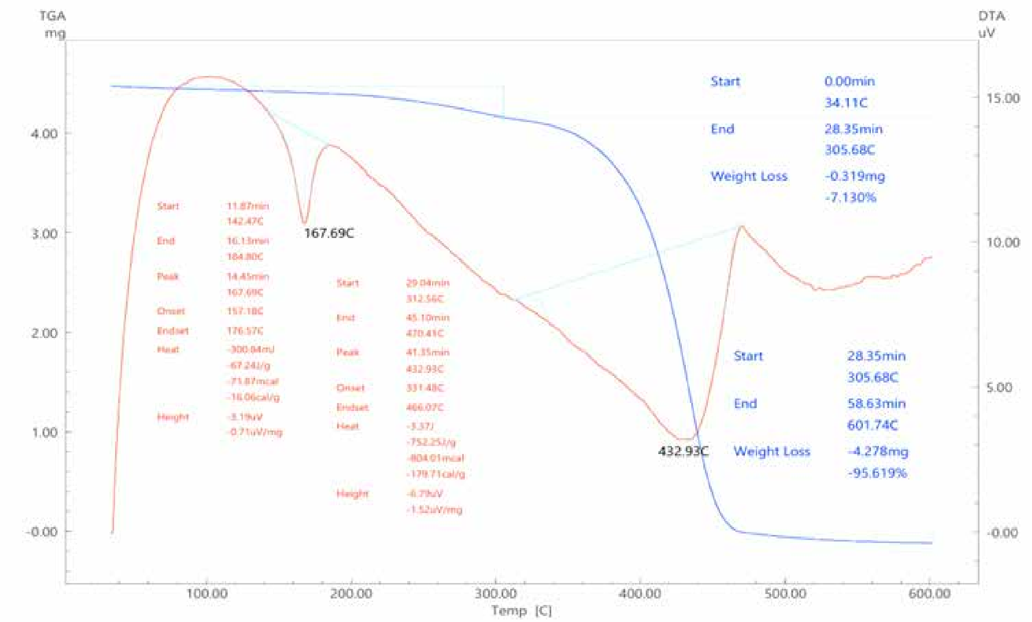
here: Δm is the decrease in the weight of the weight, mg; $\Delta \tau$ is the time interval, minutes.

Discussion of the results

At present, industrialized countries pay special attention to the production of modified polymer materials. This is achieved by adding various organic modifiers to obtain new types of materials based on recycled polyethylene and organic modifiers. The use of materials based on recycled polyethylene as various consumer products is considered to be very promising and economically beneficial for the national economy. Two methods of modifying polymer materials are used. The first method is structural modification of polymers, the second is chemical modification. Modification of polymeric materials with chemical reagents and agents is carried out by adding chemical reagents that process chemical bonds with macromolecules of the original polymer raw materials.

The main goal of this work is to obtain a new type of heat-resistant modified polymer materials. It is known that nitrogen-containing organic modifiers increase plasticizing properties, and salts of organic acids increase the flame-retardant properties of polymeric materials. From this point of view, samples of the following composition were taken for the study: polyethylene (PE), sulfur (S), sodium acetate (CH3COONa), melamine and polypropylene oligomer (o-PP) in accordance with the quantitative ratios of 50:1:1:1:1 (SMA-1 (from primary polyethylene)), 50:1:1:1:1 (SMA-2), 50:0.5:0.5:0.5 (SMA-3) and 50:1.5:1.5:1.5 (SMA-4). The heat resistance of the obtained polymer materials was studied. Below is the DTA analysis curve of the SMA-1 sample.

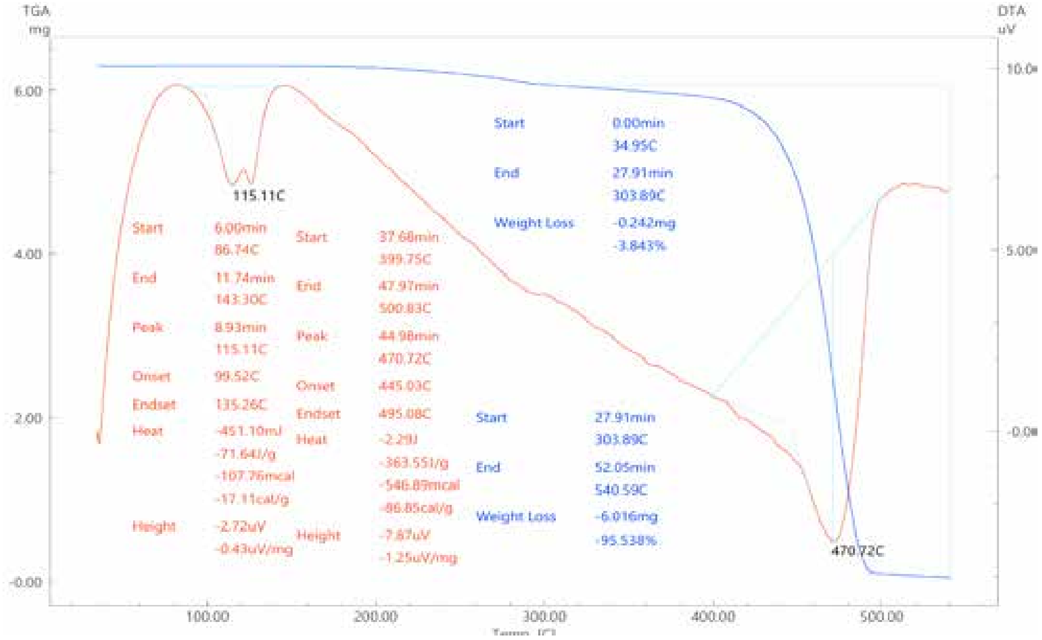
Figure 1. *Derivatogram of a sample containing CMA-1*



According to the data obtained, the initial decomposition temperature of the sample is 34.11 ºC, and the final temperature is 305.68 ºC. Mass loss under the influence of temperature for the CMA-1 sample was 7.13%. The quantitative weight loss during the initial degradation period of this CMA-1 sample is 0.319 mg in the range from 0.00 minutes to 28.35 minutes. The second temperature decomposition period of the sample was 28.35 minutes and the temperature reading was 305.68 °C. The final temperature of this second decomposition period was 601.74 °C. The time required for this decomposition was 28.35 minutes and 58.63 minutes. The mass loss of the CMA-1 sample during this second degradation period was 4.278 mg, or 95.61%. In the course of the study, two heat absorption curves are observed on the derivatogram of this sample containing CMA-1. These absorption curves have been found to be at temperatures of 167.69 °C and 432.93 °C.

Similarly, the analytical DTA curve of a sample containing CMA-2 was studied. Figure 2 shows the derivatogram of the CMA-2 sample.

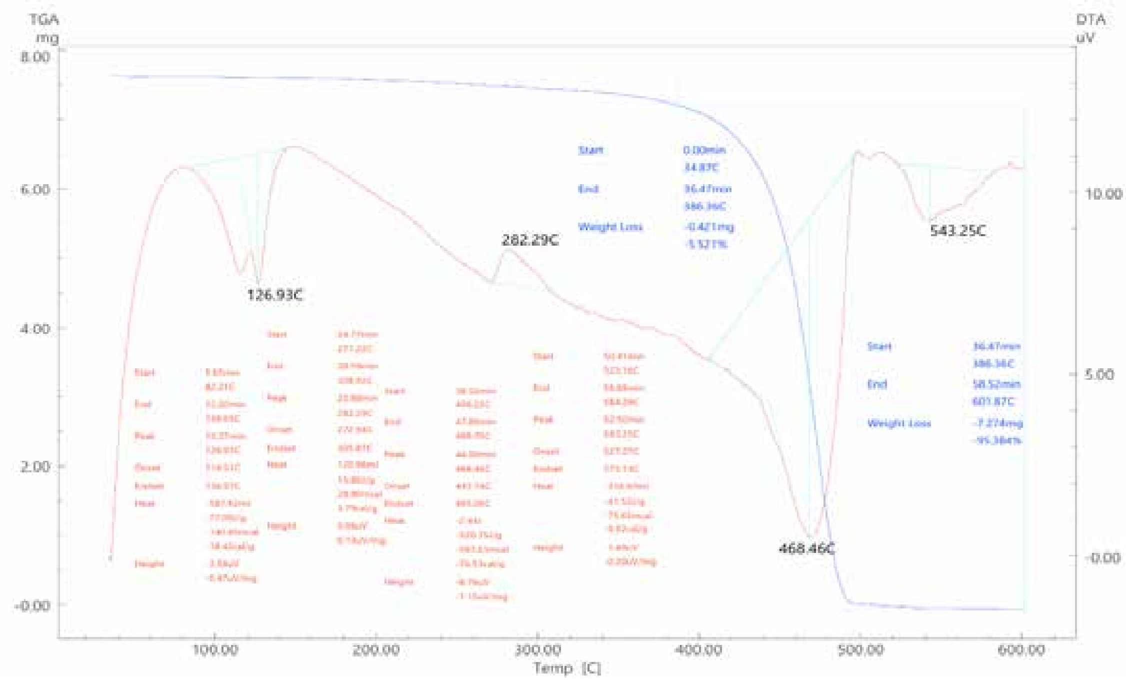
Figure 2. *Sample CMA-2 Derivatogram*



According to the data of Figure-2, it was determined that the initial decomposition temperature of the CMA-2 sample was 34.95 ºC, and the final temperature was 303.89 ºC. It was established that during the decomposition of the CMA-2 sample at this temperature, a mass loss of 3.84% was observed. The quantitative weight loss of the same sample was 0.242 mg between 0.00 min and 27.91 min. The start time of the second decomposition period under the influence of temperature for this CMA-2 sample was 27.91 minutes, and the temperature reading was 303.89 °C. The final temperature of this second decomposition period was 540.59 °C. The decomposition time was found to start after 27.91 minutes and end after 52.05 minutes. The weight loss at the second stage of decomposition was 6.01 mg, or 95.53%. As can be seen from the derivatogram of this CMA-2 sample obtained during the study, two heat absorption lines are observed during the decomposition period under the influence of temperature. These absorption curves were found to correspond to temperatures of 115.11 °C and 470.72 °C.

The analytical curve of the DTA of the CMA-3 sample was also studied below.

Figure 3. *CMA-3 Sample Derivatogram*



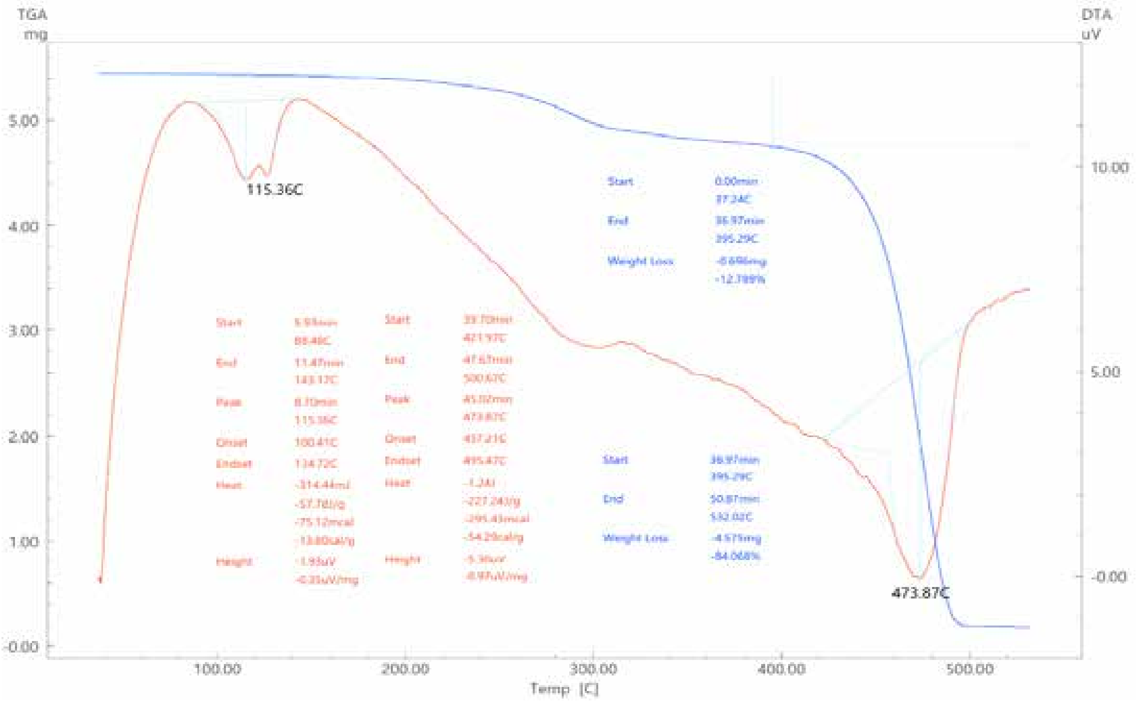
According to the data obtained, the initial decomposition temperature of the CMA-3 sample was 34.87 ºC, and the final temperature was 386.36 ºC. Mass loss during decomposition of the CMA-3 sample at this temperature was 5.521%. It was found that the mass loss during the initial period of decomposition of the same sample containing CMA-3 was 0.242 mg in the range from 0.00 minutes to 36.47 minutes. The second decomposition period of this sample under the influence of temperature was 36.47 minutes, and the temperature reading was 386.36 °C. The final temperature of this second decomposition was 601.87 °C. It was found that the time required for this decomposition, It started after 36.47 minutes and ended after 58.52 minutes. It was found that the weight loss of the CMA-3 sample during this period was 7.27 mg or 95.38%. In the course of the study, four heat absorption curves are observed on the derivatogram of this sample. These curves have been found to correspond to temperatures of 126.93 °C, 282.29 °C, 468.46 °C and 543.25 °C.

The analytical DTA curve of the CMA-4 sample was also studied.

According to the data obtained, the initial decomposition temperature of the CMA-4 sample was 37.24 ºC, and the final temperature was 395.29 ºC. Mass loss in this temperature range was 12.78%. The quantitative weight loss during the initial decomposition period of the same CMA-4 sample was 0.696

mg in the range from 0.00 minutes to 36.97 minutes. It was found that the time of the beginning of the second decomposition period under the influence of the temperature of this sample was 36.97 minutes, and the temperature index was 395.29 °C. The final temperature of the second decomposition period was 532.02 °C. It was found that the decomposition time was 36.97 minutes and 50.87 minutes. The loss of mass and time of the second resolution period was 4.57 mg, 84.06%. In the course of the study, two heat absorption curves were obtained during the decomposition period of a sample containing SMA-4 under the influence of temperature. These absorption curves were found to correspond to temperatures of 115.36 °C and 473.87 °C.

Figure 4. *Sample CMA-4 Derivatogram*



The results from the data analysed above are summarized in tables 1 and 2 below.

Table 1. *Results of Thermogravimetric Analysis of Polymer Material Based on Secondary Polyethylene Matrix (1st Decomposition Period)*

Temperature range. °C	Duration of decay. min.	Loss weight. mg	Loss Weight. %
SMA-1 ratio: 50:1:1:1:1			
34.11–305.68	0.00–28.35	0.319	7.13
CMA-2 ratio: 50:1:1:1:1			
34.95–303.89	0.00–27.91	0.242	3.84
CMA-3 ratio: 50:0.5:0.5:0.5:0.5			
34.87–386.36	0.00–36.47	0.242	5.52
CMA-4 ratio: 50:1.5:1.5:1.5:1.5			
37.24–395.29	0.00–36.97	0.696	12.78

As can be seen from the data presented in Table 1, there is no significant difference between the initial decomposition temperatures and decomposition time of the CMA-1 sample and the CMA-2 sample. However, it can be noted that the difference in weight loss between these samples has changed significantly. Comparing the results of the

CMA-1 and CMA-2 samples presented above with the results of the CMA-3 sample, a significant difference can be noticed. that the temperature in the first period of decomposition (386.36^{0}C) is higher, and the duration (36.47 minutes) is slightly longer. Similarly, the results of the three above samples were compared with those ofCMA-4. The results show that the initial decomposition temperature of the CMA-4 sample (37.24–395.29 °C) is higher, and the decomposition time is also longer. However, it was found that the mass loss of this CMA-4 sample was slightly higher than that of the three samples mentioned above.

Table 2 shows the results of the second decomposition of these samples.

Table 2. *Results of thermogravimetric analysis of polymeric material based on secondary polyethylene matrix (2nd decomposition period)*

Temperature range, °C	Duration of decay, min.	Loss weight, mg	Loss Weight, %
	SMA-1 ratio: 50:1:1:1:1		
305.68–601.74	28.35–58.63	4.278	95.61
	CMA-2 ratio: 50:1:1:1:1		
303.89–540.59	27.91–52.05	6.01	95.53
	CMA-3 ratio: 50:0.5:0.5:0.5:0.5		
386.36–601.87	36.47–58.52	7.27	95.38
	CMA-4 ratio: 50:1.5:1.5:1.5:1.5		
395.29–532.02	36.97–50.87	4.570	84.06

Analysis of the data presented in Table 2 shows that the difference between the temperature and duration of secondary degradation of the CMA-1 sample derived from virgin polyethylene and the CMA-2 sample derived from recycled polyethylene has not changed significantly, i.e. the temperature in the CMA-2 sample has decreased. When comparing the results of the CMA-1 and CMA-2 samples presented above with the CMA-3 sample, there is a significant difference. that the temperature in the second decomposition period (601.87^{0}C) is higher and the duration (58.52 minutes) is slightly longer. Similarly, comparing the results of the above three samples with those of CMA-4, it can be observed that the temperature of the second decomposition period (532.02^{0}C)and the decomposition time of theCMA-4 sample also decreased. However, it can be observed that the mass loss of this CMA-4 sample is slightly lower compared to the CMA-2 and CMA-3 samples.

Findings. As a result of the destruction of recycled polyethylene, carbon-carbon bonds arise in some parts of the chain due to the disproportion of hydrogen atoms from methylene groups that are part of the polymer chain. As a result, chemical bonds are formed between the macromolecules of the thermally destructed polymer material and chemically binding reagents polypropylene due to the breaking of the π bonds of double bonds. In addition, the modified sulfur contributes to the vulcanization of the polyethylene product by forming sulfide bridges between the macromolecules of recycled polyethylene. Such polymeric materials have increased heat resistance, reduced flammability, increased resistance to oxidation, as well as increased resistance to weathering, aggressive environments and light compared to products made of pure polyethylene.

References

Mamatova Sh.B., Qurbonov M.J., Safarova M.A. Modification and study of the properties of recycled polyethylene // Development of science. 2024. – No. 1. – P. 157-164.

Mamatova Sh.B., Kurbanov M.Zh. Production of building materials from polyethylene waste on the basis of secondary processing // Proceedings of KarSU, 2022. – No 5/1. – P. 71–75.

Mamatova Sh. B., Kurbanóv M. J., Safarova M. A., Izbasarova G. Modification of Secondary Polyethylene on the Basis of Sulfur and Melamine // Collection of Scientific Articles on the Results of the Work of the International Scientific Forum "Science and Innovations: Modern Concessions" – Moscow. – 2024. – P. 129-135. DOI 10.34660/INF.2024.38.92.018.

Mamatova, Sh. B., Kurbanov, M. Zh. Study of Physicochemical Properties of Melamine Modification of Secondary Polyethylene//Universum: Chemistry and Biology. – 2023. – No. 10-2 (112). – P. 33-39. URL: https://7universum.c om/en/нature/archive/item/16027

Mamatova Sh.B., Qurbonov M.J. Study of Thermogravimetric Analysis of Secondary Polyethylene and Melamine Modification // Modern Problems of Theoretical and Experimental Chemistry and Chemical Technology. Scientific and Practical Materials of the International Conference. – Karshi, 2023. – October 20. – P. 217-218.

Mamatova Sh., Safarova M., Davronova G., Raxmatova G., Makhmayorov J., Abdullayev B., Kurbanov M. Determination of the Time of Induction Oxidation of a Secondary Polyethylene Composition // New Materials, Compounds and Their Applications. – 2024. – 8(2). – P. 223-232. URL: https://doi.org/10.62476/nmca82223

Mamatova Sh.B., Qurbanov M.J., To'rayeva M. Determination of the flammability of modified secondary polyethylene // Actual problems of chemistry. Republican Scientific and Practical Conference. – Urganch, 2024. – 21iyun. –B. 402-403.

submitted 08.10.2025;
accepted for publication 22.10.2025;
published 26.11.2025

Contact: safarovamatluba86@gmail.com; davranovaguzal1988@gmail.com;
mengniqulqurbonov@gmail.com; dilnozashavkatova@gmail.com