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STUDY OF THE THERMAL DECOMPOSITION KINETICS AND THERMODYNAMIC PARAMETERS OF ZINC PHTHALOCYANINE PIGMENT SYNTHESIZED FROM ZINC CHLORIDE

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Annotatsiya. Ushbu tadqiqot ishida sintez qilingan rux ftalosianin (ZnPc) pigmentining termik barqarorligi differensial termik analiz (DTA) hamda termogravimetrik analiz (TGA) usullari yordamida 30–600 °C harorat oralig‘ida o‘rganildi. Olingan DTA egri chizig‘ida ikkita endotermik cho‘qqi kuzatildi. Birinchi bosqichda 212,26 °C haroratda 206,12 J/g solishtirma issiqlik effekti bilan dastlabki destruksiya jarayoni qayd etildi. Ikkinchi asosiy bosqichda 375,10 °C haroratda 789,99 J/g qiymatga ega kuchli endotermik effekt kuzatildi, bu esa rux ftalosianin makrotsiklik halqasining to‘liq parchalanishini ko‘rsatadi. TGA va DTA tahlil natijalari sintez qilingan pigmentning yuqori termik barqarorlikka ega ekanligini tasdiqlaydi. Kinetik hisoblashlarga ko‘ra, asosiy parchalanish bosqichi uchun aktivlanish energiyasi Ea = 148,6 kJ/mol, aktivlanish entalpiyasi esa ΔH = 143,36 kJ/mol ga teng ekanligi aniqlandi. Olingan natijalar rux ftalosianin pigmentini polimer materiallar uchun barqaror rang beruvchi komponent sifatida qo‘llash mumkinligini ko‘rsatadi.

Kalit so‘zlar: Rux ftalosianin, TGA/DTA, termik parchalanish, aktivlanish energiyasi (Ea), entalpiya, massa yo‘qolishi, kinetik tahlil.

Аннотация. В данной работе термическая стабильность синтезированного пигмента фталоцианина цинка (ZnPc) была исследована в диапазоне температур 30–600 °C с использованием методов дифференциального термического анализа (DTA) и термогравиметрического анализа (TGA). На полученной кривой DTA наблюдаются два эндотермических пика. На первом этапе при температуре 212,26 °C наблюдался начальный процесс деструкции с удельным тепловым эффектом 206,12 J/g. Второй основной этап характеризуется выраженным эндотермическим эффектом при температуре 375,10 °C со значением 789,99 J/g, что свидетельствует о полном разложении макроциклического кольца фталоцианина цинка. Результаты анализов TGA

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и DTA подтверждают высокую термическую стабильность синтезированного пигмента. Согласно кинетическим расчетам, энергия активации основного этапа разложения составляет Ea = 148,6 кДж/моль, а энтальпия активации равна ΔH = 143,36 кДж/моль. Полученные результаты показывают, что пигмент фталоцианина цинка может использоваться в качестве стабильного красящего компонента для полимерных материалов.

Ключевые слова: Фталоцианин цинка, TGA/DTA, термическая деструкция, энергия активации (Ea), энтальпия, потеря массы, кинетический анализ.

Abstract. In this study, the thermal stability of synthesized zinc phthalocyanine (ZnPc) pigment was investigated in the temperature range of 30–600 °C using differential thermal analysis (DTA) and thermogravimetric analysis (TGA). The obtained DTA curve exhibited two endothermic peaks. In the first stage, the initial destruction process was observed at 212,26 °C with a specific heat effect of 206,12 J/g. The second main stage showed a strong endothermic effect at 375,10 °C with a value of 789,99 J/g, which indicates the complete decomposition of the zinc phthalocyanine macrocyclic ring. The results of TGA and DTA analyses confirm that the synthesized pigment possesses high thermal stability. According to the kinetic calculations, the activation energy for the main decomposition stage was found to be Ea = 148,6 kJ/mol, while the activation enthalpy was determined as ΔH = 143,36 kJ/mol. The obtained results indicate that zinc phthalocyanine pigment can be used as a stable coloring component in polymer materials.

Keywords: Zinc phthalocyanine, TGA/DTA, thermal decomposition, activation energy (Ea), enthalpy, mass loss, kinetic analysis.\

INTRODUCTION.

LITERATURE REVIEW. At present, the demand for organic semiconductors and pigments is steadily increasing. In the production of substances with such properties, metal phthalocyanines obtained on the basis of phthalocyanine possess a wide range of functional characteristics and are widely used as stable pigments, electroactive materials, and highly efficient catalysts [1].

Thermogravimetric studies reported in the scientific literature show that metal-containing phthalocyanine pigments remain stable up to 230–350 °C, which indicates their high thermal resistance. In phthalocyanine-based pigments, the main mass loss occurs in the temperature range of 300–340 °C, which is associated with the decomposition of their organic molecular structure [2]. Copper phthalocyanine pigment based on hexamethylenediamine-1,6 was synthesized, and thermal analysis of the obtained pigment revealed that it possesses high thermal stability [3].

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A phthalocyanine complex containing copper-cobalt ions was also synthesized, and thermogravimetric analysis (TGA) and differential thermal analysis (DTA) of the obtained product were carried out. The thermogravimetric and differential thermal analysis (DTA) results of the compound were studied in detail, and its thermal stability was determined [4]. Based on the differential thermal analysis data, the activation energy and enthalpy of decomposition for the bimetallic phthalocyanine complex containing copper–cobalt ions were determined to be Ea = 458 kJ/mol and ΔH = 451,8 kJ/mol, respectively [6].

MATERIALS AND METHODS. Phthalic anhydride, zinc chloride ($ZnCl_2$), urea, catalyst, distilled water, ethanol, filter paper, Büchner funnel, and a vacuum pump were used in this study.

Synthesis Process. For the synthesis of zinc phthalocyanine pigment based on zinc chloride, 1 mol of phthalic anhydride, 5 mol of urea, 1 mol of zinc chloride, and a catalyst were placed into a special reaction vessel and thoroughly mixed. The resulting mixture was heated in a furnace at 250 °C for 1 hour. As a result, a dark green, porous, semi-solid zinc phthalocyanine product was formed in the vessel. The obtained product was then transferred to a Büchner funnel and washed several times with ethanol and subsequently with distilled water to remove unreacted reagents. After that, it was filtered using a vacuum pump.

RESULTS AND DISCUSSION.

To determine the thermal stability and decomposition mechanism of the zinc phthalocyanine pigment, thermogravimetric analysis (TGA) and differential thermal analysis (DTA) were carried out in the temperature range of 30-600 °C. Based on the analysis of the TGA curve, it can be observed that the thermal decomposition of the pigment occurs in three main stages (Figure 1).

The first decomposition stage occurs in the temperature range of 30,26–212,26 °C, where the mass loss of the sample amounts to 26,652% of the total mass, corresponding to 1,214 mg. At this stage, the main macrocyclic structure of the pigment remains preserved, and the observed mass loss is associated with the desorption of moisture adsorbed on the surface of the pigment particles, evaporation of residual organic solvents remaining after synthesis, or the release of low-molecular-weight substances weakly bound within the crystal lattice.

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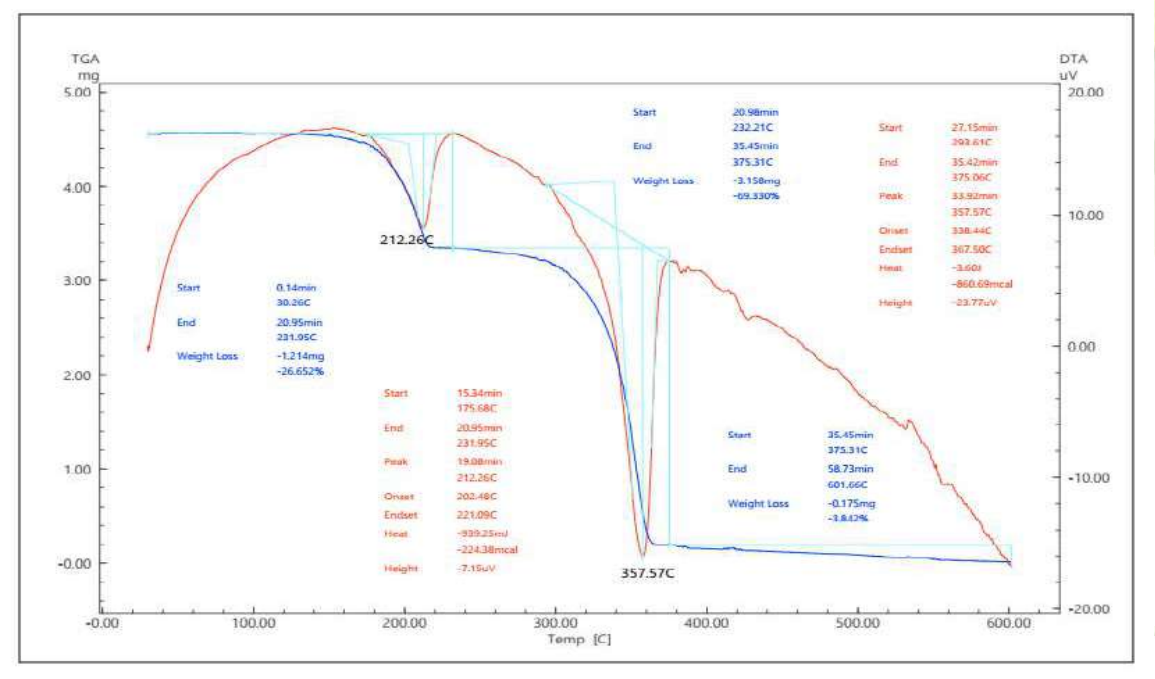


Figure 1. Derivatogram of zinc phthalocyanine pigment obtained based on zinc chloride

The first decomposition stage occurs in the temperature range of 30,26–212,26 °C, where the mass loss of the sample amounts to 26,652% of the total mass, corresponding to 1,214 mg. At this stage, the main macrocyclic structure of the pigment remains preserved, and the observed mass loss is associated with the desorption of moisture adsorbed on the surface of the pigment particles, evaporation of residual organic solvents remaining after the synthesis process, or the release of low-molecular-weight substances weakly bound within the crystal lattice.

The second decomposition stage occurs in the temperature range of 232,21–375,31 °C, and the main mass loss is observed precisely in this stage. In this process, the mass loss of the sample amounts to 69,330%, corresponding to 3,158 mg. This stage is considered the most important and intensive phase in the thermal degradation of the ZnPc pigment. During this process, the conjugated aromatic structure of the phthalocyanine macrocycle gradually begins to break down.

The third decomposition stage occurs in the temperature range of 375,31–601,66 °C, where the mass loss is relatively small, amounting to 3,842% or 0,175 mg. After 601,66 °C, no further change in mass is observed. It was determined that the zinc phthalocyanine pigment exhibits high thermal stability and remains stable over a wide temperature range. At this stage, the ZnPc pigment retains a certain amount of residual mass even at high temperatures. This confirms that phthalocyanine pigments are aromatic macrocyclic compounds with high thermal stability.

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From the obtained derivatogram, the thermal stability of the sample and the phase transformations occurring in it were studied using differential thermal analysis (DTA). Two main endothermic effects were observed on the DTA curve, indicating the decomposition stages of the obtained sample. The first endothermic effect corresponds to a peak temperature maximum at 212,26 °C. During this endothermic process, heat absorption (Q = -939,25 mJ) is observed. This process is associated with the decomposition or removal of adsorbed moisture, crystallization water molecules, or volatile organic residues remaining from the synthesis process.

The second endothermic effect corresponds to a peak temperature maximum at 357,57 °C. The amount of heat consumed in this process is relatively high and amounts to −3,60 J. This indicates the breakdown of the main macrocyclic ring of the zinc phthalocyanine molecule, the rupture of metal-ligand bonds, and the complete thermo-oxidative decomposition of the organic part.

In the DTA curve of the pigment derivatogram, the first and second endothermic decomposition stages were observed (Table 1). Using the values obtained from the endothermic peaks of the DTA curve, the activation energy of the pigment decomposition process was calculated.

Table 1

Temperature and thermal effects of the stages of zinc phthalocyanine pigment decomposition on the DTA curve

Degradation stage	Tp (°C)	Thermal effect (Q), J	Specific endothermic effect, J/g	Mass loss, %
I	212,26	0,94	206,12 J/g	26,65
II	357,57	3,6	789,99 J/g	69,33

A derivotogram of the decomposition of zinc phthalocyanine pigment was obtained at a heating rate of 10 °C/min, the activation energy (Ea) of the pigment decomposition was calculated using the Coats-Redfern method [5]. In this case, when the order of the reaction is assumed to be n=1, the activation energy of the reaction is calculated based on the following equation.

$$\log\left[\frac{-\log(1-\alpha)}{T^2}\right] = \log\left[\frac{Z\cdot R}{q\cdot E_a}\left(1-\frac{2R\cdot T}{E_a}\right)\right] - \frac{E_a}{2{,}303\ R\cdot T} \quad (1)$$

Here: α = weight loss fraction, T = temperature (K), Z = exponential coefficient, R = universal gas constant, q = heating rate, and n = reaction order. After determining the activation energy, the enthalpy value of the process was determined based on the transition state theory developed by Henry Eyring[7].

$$\Delta H = Ea - RT \quad (2)$$

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Table 2

Activation energy and enthalpy values of the stages of zinc phthalocyanine pigment decomposition

Stages of decomposition	Tp(K)	Ea (KJ/mol)	ΔH(KJ/mol)
I	485,26	85,4	81,36
II	630,57	148,6	143,36

From the results of the analysis, it can be seen that the small difference between the activation enthalpy ΔH and the activation energy Ea (4-5 kJ/mol) indicates that the destruction process occurs in the solid phase and the change in the system's disorder (entropy) is stable. The high enthalpy value of 143,36 kJ/mol observed in the second stage proves that the zinc phthalocyanine complex is very stable and requires a large amount of thermal energy for its decomposition. According to data reported in the scientific literature, the thermal decomposition of metal phthalocyanines is associated with the oxidative destruction of the macrocyclic ring, and for zinc complexes the activation energy is typically reported to be around 140–160 kJ/mol. The activation energy of the zinc phthalocyanine complex synthesized in our study was found to be 148,6 kJ/mol, which is close to these theoretical values and confirms the high structural stability of the synthesized pigment.

CONCLUSION. Based on the analysis of the thermal decomposition kinetics and thermodynamic parameters of zinc phthalocyanine pigment obtained from zinc chloride, it was determined that the pigment remains thermally stable at high temperatures. The activation energy (Ea) values calculated from the kinetic analysis indicate that the decomposition of zinc phthalocyanine pigment requires relatively high energy, which confirms the formation of strong coordination bonds between the metal and the ligand. These results demonstrate that zinc phthalocyanine pigment possesses high thermal stability and a high activation energy of decomposition, indicating that it is a stable complex compound and can be used as a pigment in polymer materials.

REFERENCES

1. G.A.Mirzoyeva, J.B.Fayziyev, N.I.Nazarov. Rux xloridi asosida ftalosianin pigmentini sintezi. Kimyo fanining muammolari, sanoat sohalariga tatbiqi va yashil
2. Texnologiyalar mavzusidagi xalqaro anjuman. Namangan-2025 yil 18-19 aprel. 479-482 b
3. Г.А.Мирзоева, С.И.Назаров, Ж.Б.Файзиев, Н.И.Назаров Синтез и термогравиметрический анализ термически стабильного фталоцианинового пигмента цинка, обладающего стабилизирующими

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свойствами для полиолефинов. // Universum: технические науки : электрон. научн.журн. 2025.10(139).-С.45-49. https://7universum.com/ru/tech/archive/item/20951

4. Содиков С.Х., Бекназаров Х.С., Джалилов А.Т., Хамраева Н.А. Исследование по приготовлению и термогравиметрическому анализу новых фталоцианиновых пигментов // Universum: технические науки: электрон. научн.журн.2024.11(128).–С.16-21

5. N.I.Nazarov, J.B.Fayziyev, S.I.Nazarov, G.A.Mirzoyeva. Mis va marganes ionlari asosida olingan bimetall ftalosiyanin kompleksini termogravimetrik hamda differensial termogravimetrik xossalarini o‘rganish // NamDU Ilmiy Axborotnomasi 2025-10-son. 173-177 b.

6. Coats A. W., Redfern J. P. Kinetic parameters from thermogravimetric data // Nature. – 1964. – Т. 201. – №. 4914. – С. 68-69.

7. Термический анализ, кинетика разложения и термодинамические параметры биметаллического фталоцианинового комплекса меди и кобальта // Universum: технические науки : электрон. научн. журн. 2026. 3(144).-С. 55-58. https://7universum.com/ru/tech/archive/item/22160

8. Petersson G. A. Perspective on “The activated complex in chemical reactions” Eyring H (1935) J Chem Phys 3: 107 //Theoretical Chemistry Accounts. – 2000. – Т. 103. – №. 3. – С. 190-195.

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