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STUDIES OF ADSORPTION, KINETICS AND THERMODYNAMICS OF HEAVY METALL IONS ON CLAY ADSORBENTS

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Abstract: Including the study investigated the isotherms of adsorption of Zn^{2+} ions in wastewater using newly modified adsorbents. Adsorption properties were analyzed based on Freyndlix, Lengmuyur, Dubinin-Radishkovich, and Temkin isotherm models. Based on the results of the study, it was found that Kaolins modified with Angren-activated kaolin (AFK) and Angren-inactive kaolin (AFMK) have the property of effectively adsorbing zinc ions in urban wastewater. The adsorption capacity of Zn^{2+} ions of synthesized adsorbents has been determined as follows: AFK — 0.151 mg/g; AFMK — 0.162 mg/g. According to adsorption isotherms analysis, the Lengmuyur model best described adsorption processes.

Keywords: adsorption, modification, effluent, bentonite, iron ions, Freyndlix, Lengmuyur, Dubinin-Radishkovich, Temkin isotherm models.

Introduction. Today, a number of R and D studies are underway in the world on the creation of activated, selective, organophilic adsorbents using clay minerals in kaolin deposits. Obtaining renewable, modified, efficient adsorbents and finding scientific solutions to their adsorption thermodynamics, in particular, the scientific justification and consistent introduction into practice of optimal conditions for the modification of kaolin (clays) gills; research into the active adsorption centers and nature of activated and modified nanoscale adsorbents; control and regulation of changes in the porosity properties of adsorbents; study of alternative conditions for the arrival of the adsorption process in gil adsorbents to equilibrium; determination of polar and nonpolar substance adsorption energy in geometric irregularities of adsorbent surfaces of adsorbate molecular structures; development of physical mechanisms of adsorption processes; application of organophilic adsorbents in industrial effluent treatment; research into the effects of organic cations on adsorption processes as well as the physical mechanisms of adsorption is an important task.

In our republic, scientifically and practically positive results are achieved in obtaining selective clay adsorbents with different properties based on local kaolins, their use in various branches of industry, in particular in wastewater treatment. Methods have been developed in this direction to synthesize import substitution sorbents from modified local kaolin minerals that are resistant to heat and chemical influences. Significant advances in their structure, physico-colloidal properties study and practical implementation in production networks, including the creation of organophilic nanoscale adsorbents based on kaolins, and changes in their ability to adsorb in relation to the nature of porosity, research on mechanisms of interaction between adsorbent-adsorbate, are of great importance in solving theoretical and practical problems of colloidal chemistry. Pollution of water resources by zinc (Zn^{2+}) ions is one of the environmental problems that negatively affects human health and aquatic ecosystems. Conventional water treatment methods often do not produce sufficient results in effective removal of Zn^{2+} ions. In recent years, researchers have studied kaolin-based adsorbents as a promising method for removing Zn^{2+} ions, showing the effectiveness of such adsorbents in treating wastewater (including sewage). Activated kaolins provide effective adsorption of Zn^{2+} ions due to their high surface area and porous structure.

The ion-exchange properties of kaolins allow effective purification of zinc ions in water. At the same time, the degree of adsorption depends on factors such as the initial concentration of Zn^{2+} ions, water chemistry, cost of Use and application requirements.

Analysis of thematic literature. Conventional water purification methods often do not produce sufficient results in effective removal of Zn^{2+} ions [1] a number of studies have been done on the basis of natural raw materials to obtain nanoscale, efficient adsorbents and to study and practice their adsorption properties [2] however, the rate of adsorption is the initial concentration of Zn^{2+} ions, water chemistry, the cost of Use and application requirements depend on factors such as [3] resulting in the total amount of zinc (II) ions (at a wavelength of λ=540 nm) determined [4,5] the Langmuir adsorption model explains adsorption as holding an adsorbate as an ideal gas under isothermal conditions. His theory began when he put forward the idea that gaseous molecules do not return elastically from the surface, but are held in a manner similar to groups of molecules in solid bodies [6,7] in adsorption processes in solution, the following factors are important: first, the nature of adsorbents, the nature of solvents from both [8] the Dubinin-Radushkevich model is often used to assess characteristic porosity and apparent free energy of adsorption [9] the Dubinin-Radushkevich (DR) adsorption isotherm model is based on the potential theory of adsorption developed by Polanyi [10] it is fundamentally robust and highly valued compared to other isotherm models due to its basic thermodynamic basis [11]

Research methodology. As an object of study, Angren kaolin was selected, which was modified with chitazin. The properties of derived adsorbents adsorbing Zn^{2+} ions in aqueous solutions have been studied.

Analysis and results. In the experiment, adsorbents measured from 5 grams were weighed on an analytical scale and added to solutions of zinc sulfate of 500 ml at different initial concentrations. The mixtures were mixed in a sheiker (magnet meshalka) for 2 hours, then infused and filtered. The total zinc concentration in the solution was determined spectrophotometrically. As a result, the total amount of zinc (II) ions (at a wavelength of λ=540 nm) is determined. Using synthesized adsorbents, the adsorption isotherms of zinc ions in solution were studied using Freindlix, Lengmuyer, Dubinin-Radishkovich, and Temkin isotherm models. With these models, the thermodynamic parameters of the zinc ion were also studied and the adsorption data were analyzed and the basic parameters of the adsorption process were determined (Figure 1). According to the results obtained, adsorption of Zn^{2+} ions to adsorbents was 0,111 mg/g on Angren-activated kaolin, and 0.164 mg/g on Angren-inactive kaolin, respectively.

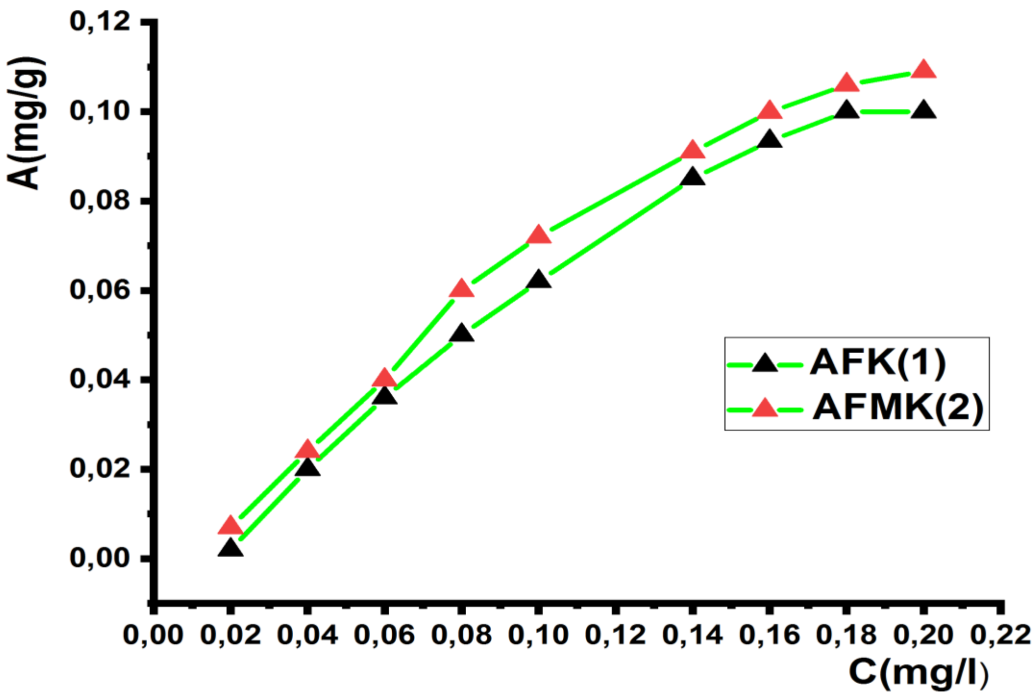

Figure 1. Zinc ion adsorption isotherms to adsorbents at 303K

There has been a dramatic increase in adsorption capacity of adsorbents in relation to an increase in the amount of adsorbtive concentration in aqueous solutions. In these cases, the accumulation of adsorbed molecules on the surface of the adsorbent surface (*arranged in the form of clusters, clusters, etc*.) is explained by the multifunctionality of the adsorbate and the strong adsorption of the solvent.

Analysis on the Freundlich model. The freundlix equation, or Freundlix adsorption isotherm, is an adsorption isotherm that represents the empirical relationship between the amount of gas adsorbed to a solid surface and the gas pressure. The results of adsorption of Zn^{2+} ions to modified adsorbents on the Freundlix model are shown in Figure 2.

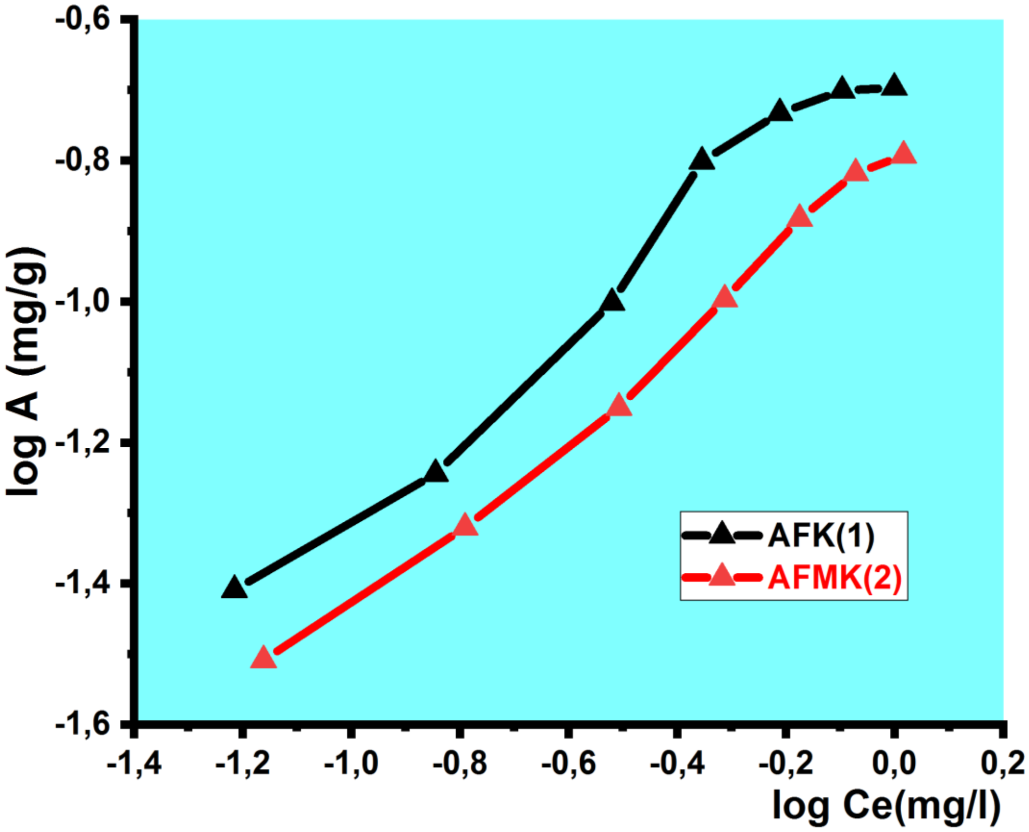

Figure 2. Adsorbents are adsorption isotherms of zinc ions at 303K on the Freundlix model

The Freundlich isotherm model states that adsorption went well when 0 < 1/n < 1. In this case, the level of adsorption decreases with an increase in concentration. We can see that in Angren-activated and Angren-inactive adsorbents, the values of 1/n are nos.0.721 and 0.64, while the values of n are greater than 1 (AFK=1.19 and AFMK=1.25). when n > 1, denotes that adsorption is strong, in which case the efficiency of adsorption decreases with increasing concentration. The isotherm indicators of the Freundlich model are given in Table 1.

Analysis on the Langmuir model. Lengmuyer explains that the adsorption model holds adsorption as an adsorbate ideal gas under isothermal conditions. His theory began when he put forward the idea that gaseous molecules do not return elastically from the surface, but are held in a manner similar to groups of molecules in solid bodies [6,7]. The experimental results obtained on the Langmuir model of adsorption of Zn^{2+} ions into adsorbents are shown in Figure 3.

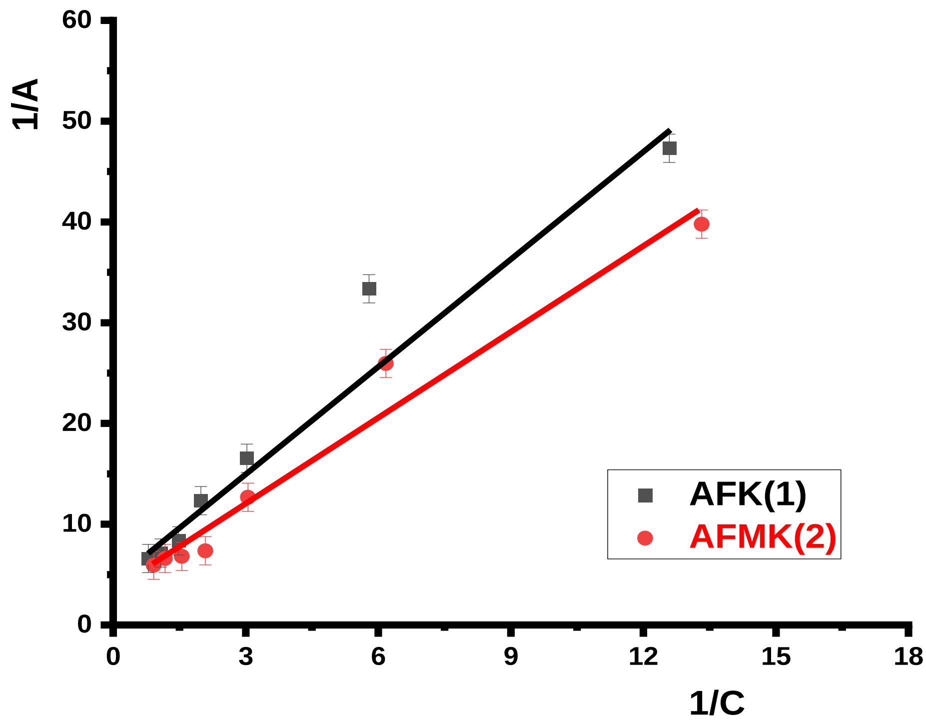

Figure 3. Adsorption isotherms on the Langmuir model of iron ion adsorption to adsorbents at 303K

The isotherm of adsorption of Zn^{2+} ions to adsorbents was found to have correlation coefficients (R^2) in the Lengmuyur model at 0.921 AFK compared to 0.964 AFMK at 0.947. In the research work, the Lengmuyur model isotherm separation coefficient (r (l)) was found to be 0.26; 0.197; 0.104, respectively. So these adsorption results correspond to the Lengmuyer model. The presence of R(L) at these values indicates the effectiveness and convenience of adsorption. The results of the Langmuir model isotherm are shown in Table 1.

Analysis on the Dubinin - Radishkovich model. The Dubinin-Radushkevich model is often used to assess characteristic porosity and apparent free energy of adsorption. The Dubinin-Radushkevich (DR) adsorption isotherm model is based on the potential theory of adsorption developed by Polanyi. It is fundamentally robust and highly valued compared to other isotherm models due to its basic thermodynamic basis. The results obtained on the Dubinin-Radushkevich model of adsorption of Zn^{+2} ions to modified adsorbents are shown in Figure 4.

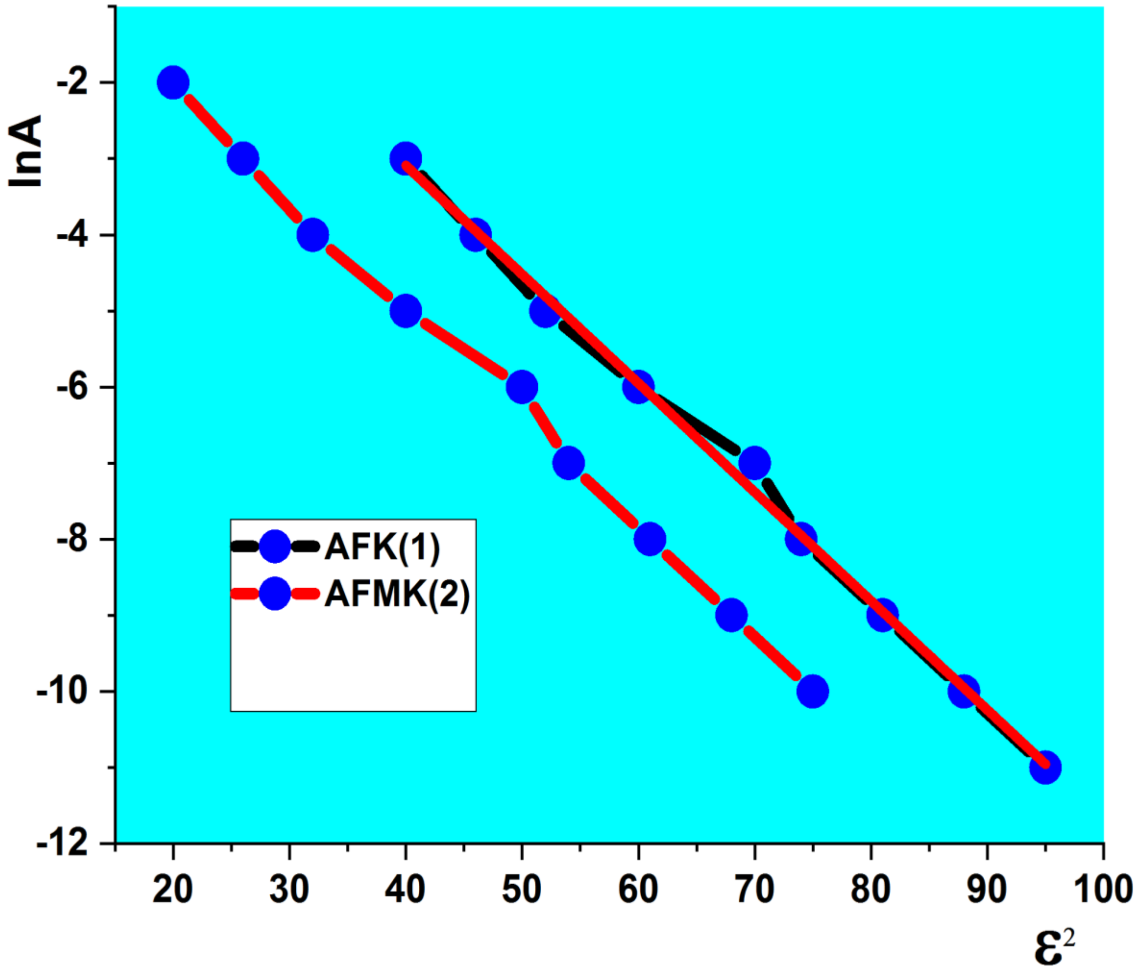

Figure 4. Adsorption isotherms of iron ions into adsorbents at 303K on the Dubinin-Radushkevich model. The values of the constants were determined by the intersection of the linear model (q_{max} =exp(intercept)) and slope tangency slope (KD-R=-slope). The adsorption isothermal Dubinin-Radushkevich model of Zn^{+2} ions to AFK, AFMK adsorbents constant values are given in Table 1

Analysis on the Temkin model. The Temkin isotherm model considers the effect of indirect adsorbate-adsorbent interaction on the adsorption process. In addition, adsorption is characterized by a uniform distribution of bond energy up to maximum bond energy. In the research work carried out, a correlation graph of qe and ln(Ce) was plotted to determine whether the isotherms obtained were consistent with the Temkin isotherm. From the slope and intersection of the drawing, the values B and KT were calculated. A drawing on the Temkin model of adsorption of Zn^{+2} ions to adsorbents is shown in Figure 5.

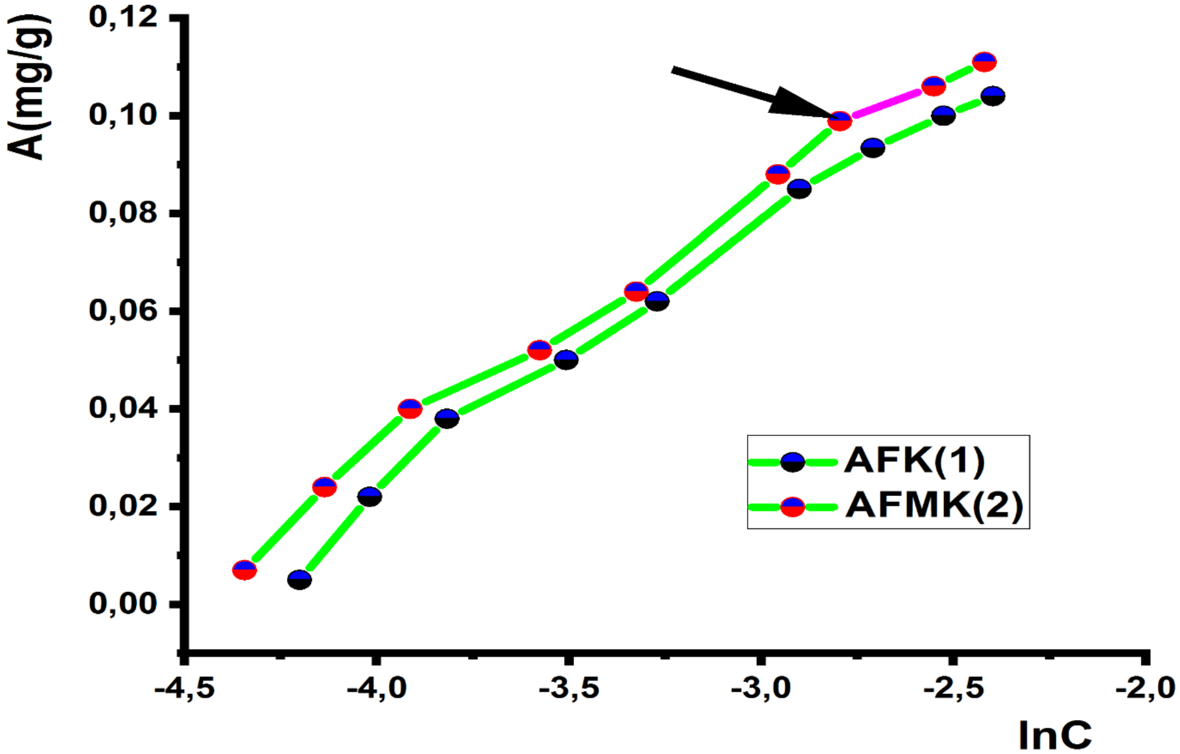

Figure 5. . Iron ions into adsorbents are adsorption isotherms at temperatures of 303K according to the Temkin model. According to the results, the correlation coefficient in this isotherm was equal to 0.989 in AFK. The isotherms of Zn^{+2} ion adsorption to AFK and AFMK adsorbents are given in Table 1 of the constant values according to the Temkin model

Table 1

Adsorbtion izotherm models	Parameters	Adsorbents	
		AFMK	AFK
Langmuir	q_{max} (mg/g)	0.206	0.235
	K_L (L/mg)	0.056	0.081
	R_L	0.261	0.197
	R^2	0.997	0.998
Freyndlix	K_F (1/mg)	0,163	0.191
	1/n	0,836	0.789
	n	1,196	1.267
	R^2	0.917	0.964
Temkin	**B_T (J/mol)**	13.354	19.541
	K_T (L/mg)	0.055	0.056
	R^2	0.969	0.989
Dubinin-Radushkevich	q_m (mg/g)	4.362	4.636
	β_d (mol²/kJ²)	$1.23 \cdot 10^{-4}$	$1.86 \cdot 10^{-5}$
	E (kj/mol)	34.4	56.9
	R^2	0.834	0.881

Table 2.

	Temp (K)	K_L	ΔG° (KJ/mol⁻¹)	ΔH° (KJ/mol⁻¹)	ΔS° (KJ/mol⁻¹)	R^2
Adsorbent	283	1,75	-1316,6987	55,926	2,481776	0,988
	293	1,83	-1472,1149			
	303	1,91	-1630,145			
	313	2,02	-1829,658			

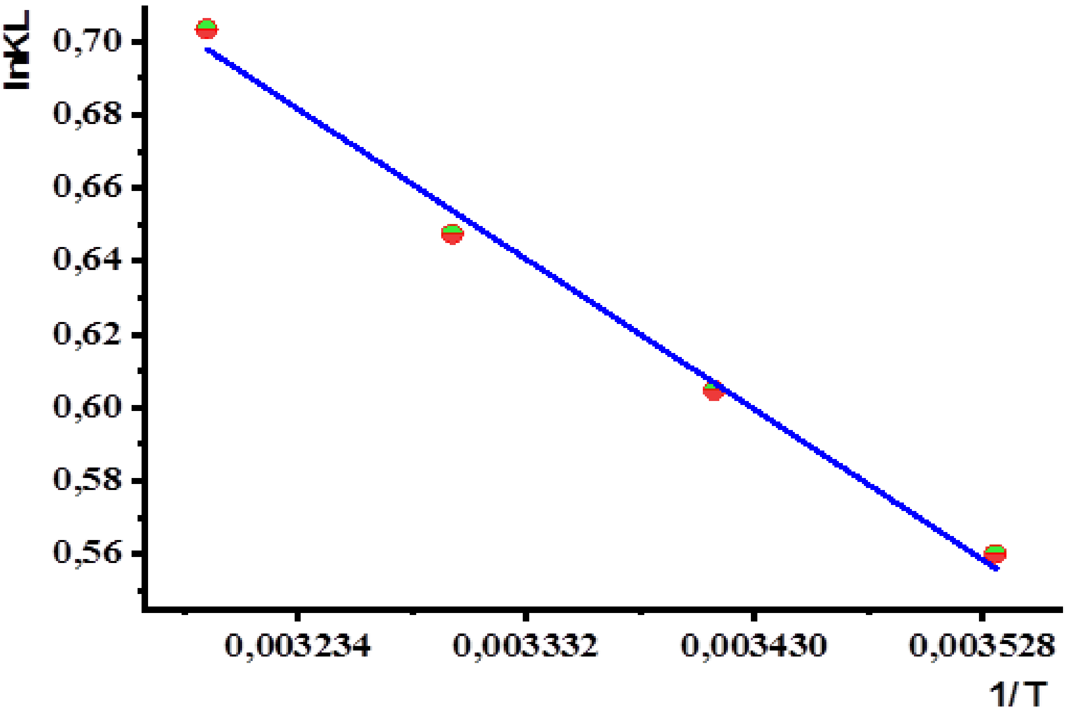

Figure 6. Thermodynamic functions for metal sorption in adsorbent

Based on the research carried out, the correlation coefficients in the Lengmuyur model were more accurately described than in the Freundlich, Temkin and Dubinin-Radiushkevich models. Adsorption capacity (qmax) of adsorbents according to the Lengmyur model was found to be 0,206 at AFK; 0,235 mg/g at AFMK.

Conclusions and suggestions. According to the results of the research carried out: the ability of synthesized adsorbents to adsorb Zn^{+2} ions has been described more accurately than other models through the Lengmyur model. In terms of adsorption capacity, the AFK adsorbent had the highest result at 0,229 mg/G. In the case of adsorption of Zn^{+2} ions, AFK has been found to have indicators of 0,151 mg/g and AFMK of 0,168 mg/G. The effectiveness of the adsorption process depends on the nature and coverage capacity of the adsorbent, and these results provide a scientific basis for the application of these models in Environmental Protection.

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