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Sorption properties of layered double hydroxides produced by ultrasonic exposure

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Abstract: Layered double hydroxides (LDH) can be classified as promising materials due to the ease of synthesis, as well as their wide scope of application. However, the process of LDH synthesis, depending on the LDH chemical composition, can take from tens of hours to several days. It was previously identified that ultrasound exposure during the LDH production significantly reduces the synthesis time, and LDHs produced in this way are interesting in relation to the study of their physicochemical properties and sorption capacity. In this work, the authors produced Mg/Fe LDHs in nitrate form by the traditional method and by the combined action of ultrasound and increased hydrostatic pressure. The resulting samples are characterized by a complex of physicochemical methods of analysis, including scanning electron microscopy (SEM), infrared spectroscopy (IR), X-ray phase analysis (XRD), and thermal gravimetric analysis (TGA) with differential scanning calorimetry (DSC). Experiments were carried out to study the sorption capacity of the obtained Fe/Mg LDH samples in relation to chromate ions under normal conditions and under the influence of ultrasound, including in combination with increased hydrostatic pressure. A photoelectric photometer was used to obtain and analyze data with quantitative values of the sorption process. Data of comprehensive analysis of the finished product indicate that the synthesized material is a Mg/Fe layered double hydroxide. X-ray phase analysis identified that the LDH synthesis using ultrasound and pressure increases the crystallinity degree of the finished product. It has been found that the sorption properties of LDHs produced by the conventional method and LDHs produced under the influence of ultrasound and pressure are different. In Mg/Fe LDHs synthesized by the conventional method, chromate sorption proceeds better than in samples synthesized using ultrasonic treatment in combination with increased hydrostatic pressure. The study shows that the sorption process of the examined LDH samples is described by different mathematical models.

Keywords: layered double hydroxides; Mg/Fe; ultrasonic synthesis; sorption properties; chromate ions.

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INTRODUCTION

Layered double hydroxides (LDHs) are considered a promising class of compounds for the creation of catalytic systems [1], biomedical materials [2], and adsorbents [3]. An LDH can be used both as a separate sorbent [4], and as an element of a composite sorbent [5]. Recently, there has been a growing number of publications on the study of the LDH ability to sorb substances polluting wastewater, i. e., pollutants. This includes substances containing heavy metals [6] or chromates [7]. In an environmental context, studies on the sorption properties of LDHs containing metals with low water environment toxicity – Mg, Al, Fe are the most interesting [8; 9].

LDHs can be used as sorbents due to their physicochemical properties. LDHs are inorganic frameworks consisting of two positively charged layers, formed by metal ions and hydroxide ions, between which mobile anions and water molecules are located [10]. In their structure and properties, they are similar to anionic clays consisting of brucite-like layers [11]. The LDH composition is expressed by the general formula:

$$\left[M^{2+}_{1-x}M^{3+}_{x}(OH)_2\right]\left(A^{n-}\right)_{x/n}\times mH_2O,$$

where M^{2+} and M^{3+} are cations of divalent and trivalent metals, respectively;
A^{n-} is an interlayer anion;
x is the molar ratio of trivalent cation to divalent cation;
n and m are the amount of interlayer water.

Due to their layered structure and electrostatic nature, layered double hydroxides can be intercalated with anions or anionic complexes of various sizes and nature, which determines the possibility of their use as promising sorption materials [12–14].

The LDH synthesis does not require complex laboratory equipment, and the synthesis process itself consists of two key stages: coprecipitation and crystallisation. The crystallisation stage, in accordance with the classical LDH synthesis method, is carried out by heating and takes from 10 h to several days [15; 16]. Relatively recently, in the literature, works have appeared on the use of ultrasound in the LDH synthesis. These works state that the ultrasound effect on the reaction mixture reduces the crystallisation stage to several tens of minutes [17–19]. The sorption properties of LDH produced in this way may differ from the sorption properties of LDH produced by the classical method. It should be noted that the LDH synthesis under the influence of ultrasound in combination with increased hydrostatic pressure, and therefore the sorption properties of such LDH, are not described at all in the literature.

The purpose of this work is to investigate the possibility of synthesising layered double hydroxides under the influence of ultrasound and pressure, as well as to study their sorption properties in relation to the CrO_4^{2-} chromate anion, compared to LDHs produced by the conventional method.

METHODS

The authors used analytically pure magnesium (II) nitrate 6-water, analytically pure iron (III) nitrate 9-water (JSC "Base of chemical reagents No. 1"), sodium hydroxide, sodium nitrate (JSC "Vekton"), potassium chromate (Sigma-Aldrich). Other chemicals, solvents, and materials were received from commercial sources and used without additional purification.

The Mg(II)/Fe(III)–NO_3^- LDH synthesis was carried out by coprecipitation. A solution of sodium hydroxide and sodium nitrate (2 and 0.25 eq., respectively) was added drop-by-drop to a solution of magnesium (II) nitrate hexahydrate, and iron (III) nitrate nonahydrate (0.75 and 0.25 eq., respectively). Further processing of the reaction mixture was carried out using one of the following methods:

1) the reaction mixture was kept at 75 °C for 72 h;

2) the reaction mixture was processed with ultrasound at a frequency of 22 kHz with an applied hydrostatic pressure of 2 atm for 1 h.

The resulting precipitate was washed with distilled water until pH=7, centrifuged (5000 rpm for 5 min), and then stored under a layer of water or dried to constant weight at 30 °C for 24 h.

The resulting samples were examined for their ability to sorption of chromate ions.

To determine the time of sorption equilibrium onset, 0.084 g of LDH, 45–47 g of water, 1 g of 0.1000 N K_2CrO_4 solution, and 0.001 g of sodium hydroxide were placed in a conical flat-bottomed flask, after that, the mixture weight was made up to 50 g by adding distilled water. The resulting suspension was stirred for 1–10 min or exposed to ultrasound, or ultrasound in combination with increased hydrostatic pressure of 2 atm. The equilibrium concentration of potassium chromate in the suspension was determined photometrically using the calibration curve method. Experimental solutions and a control solution were photometered against distilled water at a wavelength of 410 nm.

Experiments to study the sorption of LDH were carried out at a temperature of 18 °C. An LDH (0.084 g), 45–47 g of water, 0.1000 N solution of K_2CrO_4 (0.5, 1, 2, and 3 g), 0.001 g of sodium hydroxide were placed in a conical flat-bottomed flask, after that, the mixture weight was made up to 50 g by adding distilled water. The resulting suspension, was stirred for 10 min. The potassium chromate concentration in the suspension was determined photometrically, using the calibration curve method. Experimental solutions, and a control solution were photometered against distilled water at a wavelength of 410 nm. When photometering experimental solutions, the equilibrium absorbance A_e was determined, followed by the calculation of the equilibrium concentration of potassium chromate C_e.

X-ray diffraction analysis (XRF) was performed on a DRON-7 diffractometer, 2θ angular interval from 7 to 80° with a scanning step of Δ2θ=0.02° and exposure time of 7 s per point. The authors used Cu-Kα radiation (Ni-filter), which was subsequently decomposed into components Kα1 and Kα2, when processing the spectra.

Thermal gravimetric analysis (TGA) was carried out on a NETZSCH STA 449 F3 Jupiter device, using a heating rate of 10 °C/min in a temperature range of 30 to 600 °C.

The microstructure study (SEM) was carried out at the Interdisciplinary Resource Centre for Nanotechnology of the Research Park of St. Petersburg State University on a Carl Zeiss Merlin scanning microscope (Carl Zeiss AG, Oberkochen, Germany) at 10 kV, SE2 detector, working distance of 6.4 mm, pressure of $9.4\cdot10^{-7}$ mbar. Graphite was deposited by a Gatan PECS Model 682 device; deposition layer of 10 nm. Infrared (IR) spectra were recorded on a Shimadzu IRPrestige-21 spectrometer (Japan). Photometric studies were carried out using a KFK-3 photoelectric photometer.

RESULTS

Synthesis conditions, physical form, and codenames of the obtained LDHs are given in Table 1.

An image of powder LDH taken using a scanning electron microscope (Fig. 1) clearly shows "flakes", which are a consequence of its layered structure. Fig. 2 shows

an example of the LDH IR spectrum. IR spectra were recorded in the range of 4000–400 cm^{-1}. The IR spectrum contains two intense absorption bands (broad one with a maximum at 3447 cm^{-1} and narrow one with a maximum at 1340 cm^{-1}), two broadened low-intensity bands at 1642 and 750 cm^{-1}, and a band of medium intensity at 549 cm^{-1}.

The diffraction patterns of the produced LDHs demonstrate the presence of peaks characteristic of the LDH crystal lattice (Fig. 3). Fig. 3 b also contains an additional peak in the region of 2θ=40°, indicating the presence of an additional phase in the compound.

The TGA and DSC dependences for all produced LDHs are of the same type; an example of a typical thermogram is shown in Fig. 4. The thermogram shows that the thermal decomposition of the sample, goes through the stages of interlayer water removal, degradation of hydroxide layers to oxide layers, and removal of interlayer anions, respectively.

The data obtained from the experiment on the chromate sorption of Mg/Fe LDH are given in Table 2. The experimental data obtained from studying the influence of chromate weight on the sorption process are given in Table 3. Fig. 5 shows the adsorption isotherms obtained from these experimental data.

To select the most appropriate adsorption model, Langmuir (Fig. 6) and Freundlich (Fig. 7) isotherms were plotted in inverse and logarithmic coordinates, respectively.

Langmuir adsorption is described by the equation

$$\frac{c_e}{q_e} = \frac{1}{Q_m K_L} + \frac{c_e}{Q_m},$$

where q_e is the weight of adsorbed potassium chromate per LDH adsorbent unit weight, mg/g;

Table 1. *Synthesis conditions, physical form, and codenames of LDHs*
Таблица 1. *Условия синтеза, физическая форма и кодовые наименования СДГ*

Code	Synthesis conditions			Physical form
	Temperature 75 °C, 72 h in water bath	Ultrasound treatment at 22 kHz	Ultrasound treatment at 22 kHz with pressure of 2 atm	
1*i*	+			Powder
1*ii*	+			Suspension
2*i*		+	+	Powder
2*ii*		+	+	Suspension

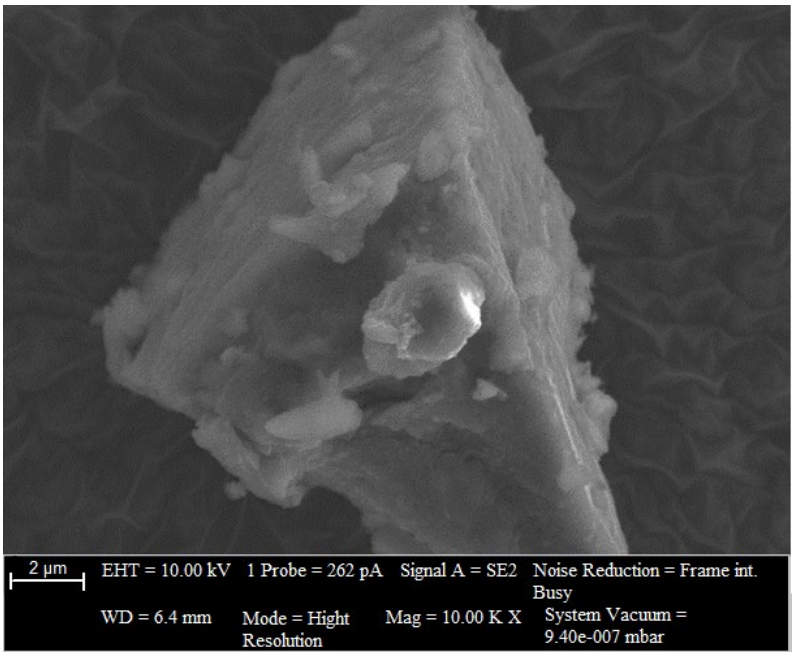

Fig. 1. *A scanning electron microscope image of the Mg(II)/Fe(III)–NO_3^- layered double hydroxide*
Рис. 1. *Снимок Mg(II)/Fe(III)–NO_3^- слоистого двойного гидроксида, сделанный на сканирующем электронном микроскопе*

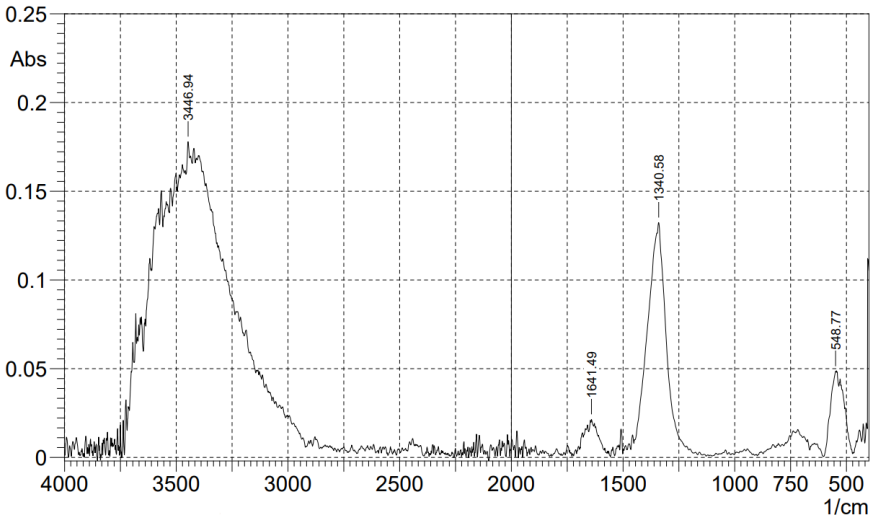

Fig. 2. *Infrared spectra of the Mg(II)/Fe(III)–NO_3^- layered double hydroxide*
Рис. 2. *Инфракрасные спектры Mg(II)/Fe(III)–NO_3^- слоистого двойного гидроксида*

C_e is an equilibrium concentration of potassium chromate calculated from photometric data, mg/l;
K_L is an adsorption free energy constant (otherwise – Langmuir affinity constant), l/mg;
Q_m is a monolayer adsorption power, mg/g.

Within the framework of Langmuir adsorption theory, it is expected that all adsorption centres are energetically equivalent, and each such centre can hold only one adsorbent particle. Therefore, the adsorbent centre has a finite capacity to adsorb an adsorbate.

Based on the graphically represented experimental data (Fig. 6), the K_L and Q_m parameters were calculated (Table 4). The Langmuir approach can be used to predict the affinity force between adsorbate and adsorbent using the dimensionless partition coefficient (R_L) (Table 3), which was determined by the equation

$$R_L = \frac{1}{(1 + K_L c_0)}.$$

At partition coefficient values $0<R_L<1$, adsorption predominates, at $R_L>1$, desorption predominates, while at $R_L=1$, so-called linear adsorption is observed, and adsorption is irreversible at $R_L=0$.

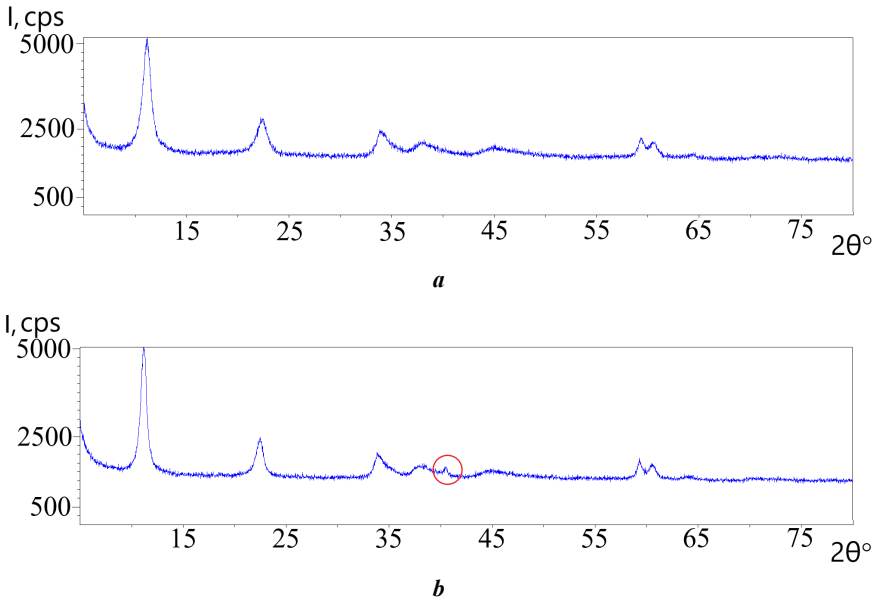

Fig. 3. *Diffraction patterns of the Mg(II)/Fe(III)–NO_3^- layered double hydroxides synthesized by the 1i (**a**) and 2i (**b**) method. The marked area is an additional peak indicating the presence of an extra phase in the compound*
Рис. 3. *Дифрактограммы Mg(II)/Fe(III)–NO_3^- слоистых двойных гидроксидов, синтезированных способом 1i (**a**) и 2i (**b**). Выделенная область – дополнительный пик, говорящий о наличии в соединении дополнительной фазы*

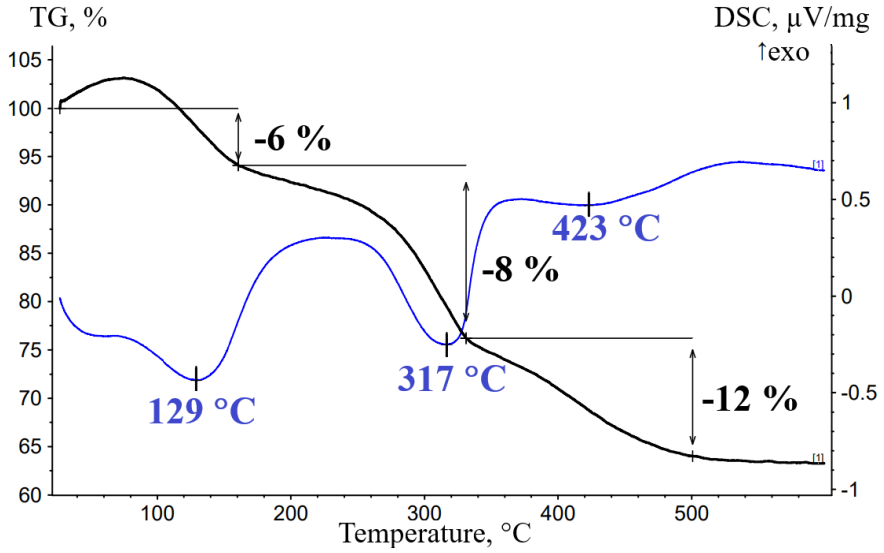

Fig. 4. *Stages of thermal decomposition of the Mg(II)/Fe(III)–NO_3^- layered double hydroxide*
Рис. 4. *Стадии термического разложения Mg(II)/Fe(III)–NO_3^- слоистого двойного гидроксида*

According to Freundlich, adsorption is described by the empirical equation

$$\lg q_e = \lg K_F + \frac{1}{n}\lg c_e,$$

where q_e is the weight of adsorbed potassium chromate per LDH adsorbent unit weight, mg/g;
K_F is a Freundlich constant, mg/g;
$1/n$ is the adsorption intensity.

Based on the graphically represented experimental data (Fig. 7), the K_F and $1/n$ parameters, as well as the partition coefficient (Table 4), were calculated.

To determine the more likely adsorption mechanism, the correlation coefficient r^2 (Table 4) for the experimental data was calculated using the Langmuir (Fig. 6) and Freundlich (Fig. 7) adsorption plots.

DISCUSSION

Chemical processes proceeding during LDH synthesis can be expressed by the following equation:

$$6Mg^{2+} + 2Fe^{3+} + 16OH^- + 2NO_3^- + 4H_2O = \\ = \left[Mg_6Fe_2(OH)_{16}\right](NO_3)_2 \times 4H_2O.$$

The SEM image of LDHs (Fig. 1) clearly demonstrates the flaky microstructure of the synthesised powder LDHs, which, in turn, is a consequence of their layered organisation. The data obtained using SEM are consistent with literature data [20–22] on other LDHs, as well as their natural analogues – cationic clays, which also have a flaky structure due to their layered morphology.

The presented IR spectra (Fig. 2) contain absorption bands that prove the presence of chemical bonds characteristic of magnesium-iron LDHs: a wide intense absorption band at 3750–3200 cm^{-1} corresponds to OH stretching vibrations of water molecules and hydroxyl groups. The presence of a broadened low-intensity absorption band at 1641 cm^{-1} is caused by bending vibrations of water molecules. Absorption bands at 1340 and 750 cm^{-1} of high and low intensity, respectively, relate to nitrate anion vibrations, while the presence of a medium-intensity band at 549 cm^{-1} is caused by covalent metal-oxygen coordination bonds.

The diffraction patterns of the resulting LDHs are almost identical (Fig. 3) and contain a set of basal reflections typical for LDHs with a hydrotalcite structure. All samples are characterised by a hexagonal crystal system. These facts indicate a layered structure of the produced LDHs and allow attributing the resulting LDHs to the hydrotalcite crystallographic type. In addition, calculations using the obtained experimental data indicate that the crystallinity of the samples is maximum for 2*i* and 2*ii*. Moreover, in the case of 2*i* and 2*ii* samples, an extra layer line appears in the diffraction patterns in the region of 2θ=40.50° (*d*=2.225 Å).

TGA/DSC analysis of LDH samples (Fig. 4) showed that, in general, the thermal decomposition of the samples proceeds in three stages. At the first stage, a loss of interlayer water occurs, which is accompanied by a pronounced endo-effect (weight loss is about 6 %). At the second stage, also accompanied by a visible endo-effect, the hydrotalcite-like hydroxide layers are destroyed, accompanied by their transformation into predominantly oxide-type layered structures. At the second stage, the NO_3^- anion also decomposes. The weight loss at the second stage is about 18 %. The third stage is accompanied by a weakly expressed, barely noticeable endo-effect; the final decomposition of residual hydroxides and the NO_2^- anion occurs. As a result, a mixture of iron (III) and magnesium (II) oxides is formed, and the weight loss is about 12 %.

The data obtained when studying the LDH sorption properties in relation to chromate ions (Table 2) indicate that with normal stirring, sorption equilibrium is achieved within 5 min after the experiment onset (Table 2, No. 1, 4, 7). However, the maximum sorption is observed after 1 min.

Table 2. *Comparison of sorption efficiency under various conditions*
Таблица 2. *Сравнение эффективности сорбции в различных условиях*

No.	Sorption conditions		Optical density of control solution A_0	Optical density of experimental solution A_e	Optical density difference ΔA
	Treatment*	Time, min			
1	18 °C, stirring (1*i*)	1	0.339	0.210	0.129
2	18 °C, stirring (2*ii*)	1	0.339	0.229	0.110
3	18 °C, stirring (1*ii*)	5	0.339	0.220	0.119
4	18 °C, stirring (1*i*)	5	0.337	0.236	0.101
5	18 °C, stirring (2*ii*)	5	0.339	0.241	0.098
6	18 °C, stirring (2*i*)	5	0.339	0.267	0.072
7	18 °C, stirring (1*i*)	10	0.378	0.276	0.102
8	US 22 kHz (1*ii*)	5	0.338	0.211	0.127
9	US 22 kHz (2*ii*)	5	0.338	0.222	0.116
10	US 22 kHz, *p*=2 atm (1*ii*)	5	0.351	0.199	0.152
11	US 22 kHz, *p*=2 atm (2*ii*)	5	0.351	0.223	0.128
12	US 22 kHz, *p*=2 atm (1*ii*)	0.5	0.343	0.228	0.115
13	US 22 kHz, *p*=2 atm (2*ii*)	0.5	0.337	0.246	0.091
14	US 22 kHz, *p*=2 atm (1*i*)	0.5	0.337	0.233	0.104
15	US 22 kHz, *p*=2 atm (2*i*)	0.5	0.337	0.234	0.103
16	US 22 kHz (1*ii*)	0.5	0.348	0.200	0.148
17	US 22 kHz (2*ii*)	0.5	0.348	0.219	0.129

*Note. * LHD code is given in brackets (see Table 1).*
*Примечание. * В скобках указан код СДГ (см. таблицу 1).*

Table 3. *Adsorption at constant LDH weight and different chromate weight*
Таблица 3. *Адсорбция при постоянной массе СДГ и разной массе хромата*

m_0 0.1000 N of K_2CrO_4 solution, g	Concentration in the initial solution C_0, mg/l	Optical density A_e	Weight of sorbate chromate m_e K_2CrO_4, mg	Concentration of sorbate chromate C_e, mg/l	Adsorption value q_e, mg/g	LDH m, mg
for 1*i* LDH						
0.500	64.7	0.126	2.20	44.0	12.4	0.0840
1.00	129	0.276	4.82	96.5	19.7	0.0840
2.00	258	0.581	10.2	203	33.3	0.0840
3.00	388	0.898	15.7	314	44.5	0.0840
for 2*i* LDH						
0.500	64.7	0.096	1.80	36	17.22	0.0840
1.00	129	0.256	4.81	96.2	19.68	0.0840
2.00	258	0.578	10.87	217.4	24.36	0.0840
3.00	388	0.906	17.03	340.6	28.44	0.0840

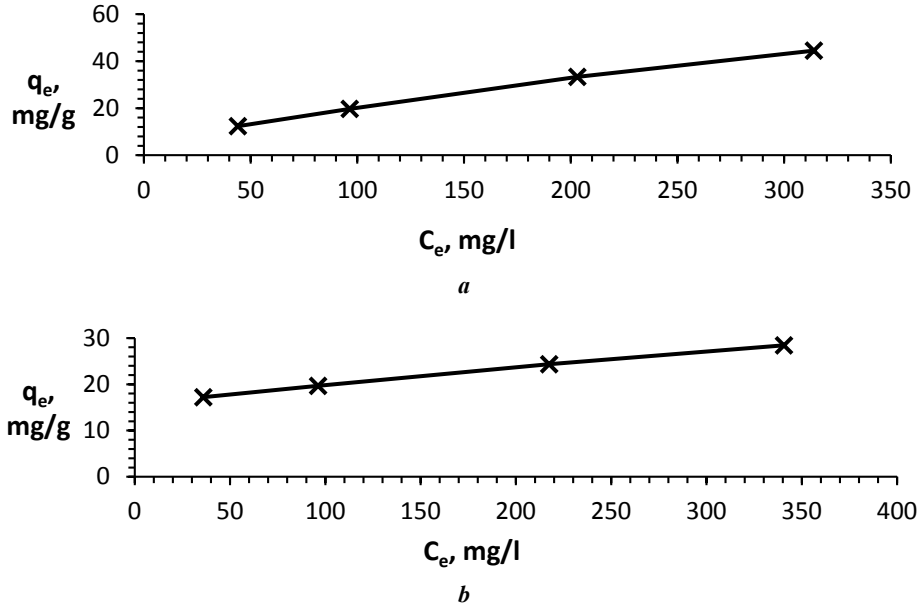

Fig. 5. *Adsorption isotherm of potassium chromate for 1i (**a**) and 2i (**b**)*
Рис. 5. *Изотерма адсорбции хромата калия для 1i (**a**) и 2i (**b**)*

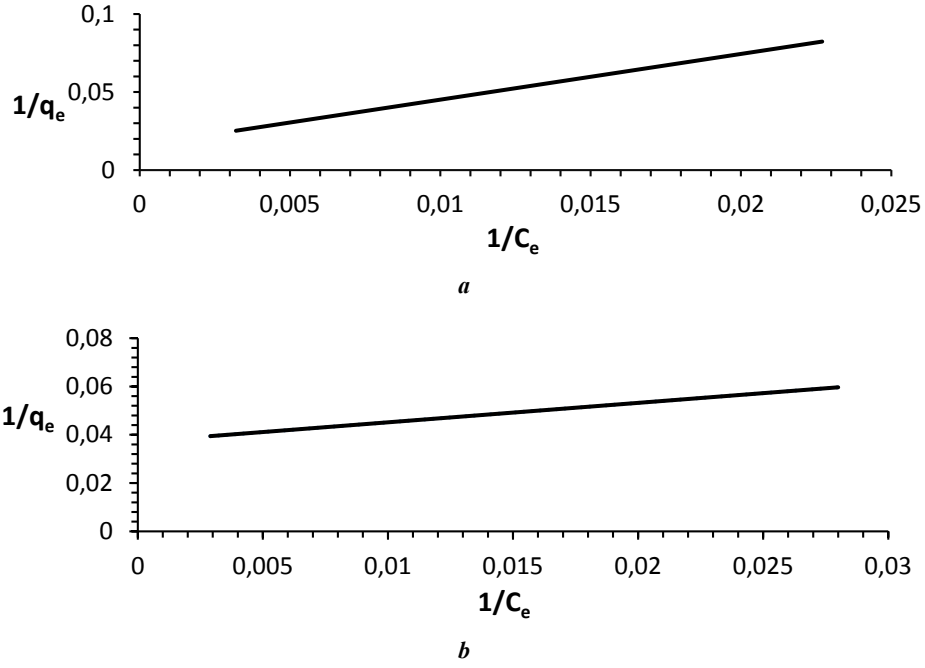

Fig. 6. *Langmuir adsorption isotherm for 1i (**a**) and 2i (**b**)*
Рис. 6. *Изотерма адсорбции для 1i (**a**) и 2i (**b**) по Ленгмюру*

One should note that the use of the suspension LDH allows achieving slightly better sorption results than the use of the powder form (Table 2, No. 3 and 4, 5 and 6).

Experimental data (Table 2) indicate that when using the same hydroxide forms as sorbents, sorption improves for the same time when the system is exposed to ultrasound, and even greater when ultrasound is applied in combination with increased hydrostatic pressure (Table 2, No. 3, 8, 10 or 5, 9, 11).

In the case of ultrasonic treatment of sorption systems, the maximum sorption is observed in 0.5 min, and by 5 min of exposure, partial desorption of chromate ions occurs (Table 2, No. 8 and 16, 9 and 17). In the case of simultaneous action of ultrasound and pressure, the amount of sorbate chromate increases with an increase in sorption time from 0.5 to 5 min by approximately 30 % (Table 2, No. 10 and 12, 11 and 13). To determine accurately the time of maximum sorption, additional experiments are required.

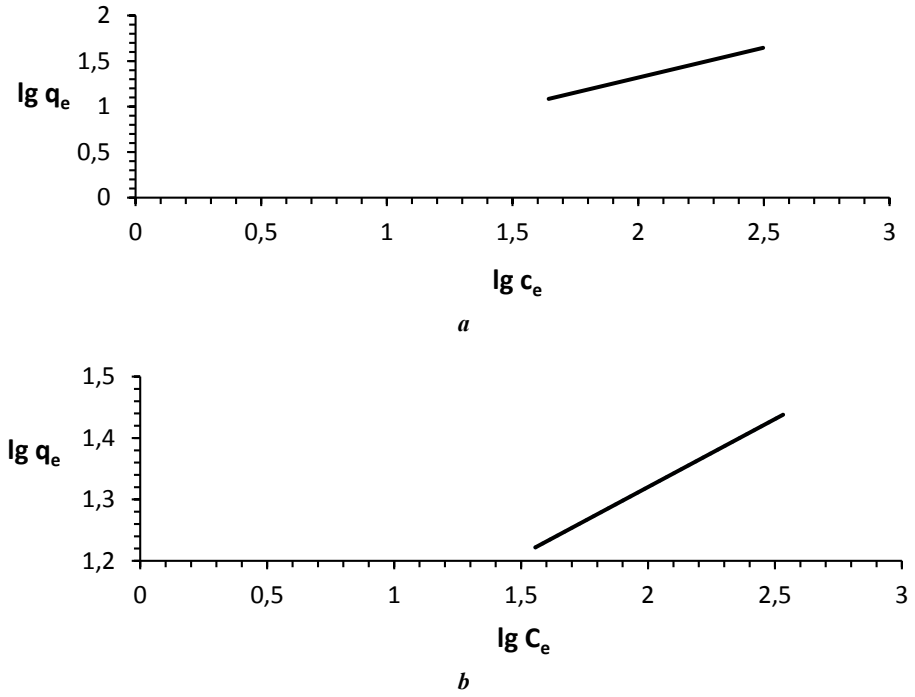

Fig. 7. *Freundlich adsorption isotherm for 1i (**a**) and 2i (**b**)*
Рис. 7. *Изотерма адсорбции для 1i (**a**) и 2i (**b**) по Фрейндлиху*

Table 4. *Comparison of Langmuir and Freundlich adsorption parameters*
Таблица 4. *Сравнение параметров адсорбции по Ленгмюру и Фрейндлиху*

According to Langmuir				According to Freundlich			
K_L	Q_m	R_L	r^2_L	K_F	1/n	R_L	r^2_F
for 1*i* LDH							
0.0032	62.50	0.7073	0.99275	1.01	0.656	0.0076	0.99927
for 2*i* LDH							
0.028	27.03	0.2168	0.8200	–	–	–	–

It is important to note that, as a rule, 1*i* and 1*ii* LDHs produced by the conventional method, demonstrate better sorption results than 2*i* and 2*ii* LDHs produced under the influence of ultrasound and pressure (Table 2, ΔA values for No. 3 and 5, 4 and 6, 8 and 9, 10 and 11, 12 and 13, 16 and 17).

The adsorption of LDH chromate ions obtained by the classical method (1*i*) is well described by both the Langmuir and Freundlich models. Although the correlation coefficients represented in Table 4 are very close, the slightly larger correlation coefficient r^2_F indicates that the adsorption of chromate ions by 1*i* LDH is somewhat more consistent with the Freundlich equation. In the case of an LDH produced by treating the reaction mixture with ultrasound at elevated pressure (2*i*), the adsorption of chromate ions is well described by the Langmuir model and cannot be described by the Freundlich equation. This is because, according to the Freundlich model, the straight isotherm line must intersect the ordinate axis in the region of negative values, which does not agree with the experimental data. Thus, it seems possible to compare the efficiency of 1*i* and 2*i* samples only within the framework of the Langmuir model. Within the framework of this model, the adsorption power of LDH produced by the classical method (1*i*) is almost 2 times higher than the power of LDH produced under the influence of ultrasound in combination with pressure (2*i*), as evidenced by the Q_m values (Table 4). Moreover, the values of the Langmuir constant K_L given in Table 4 indicate that the affinity of chromate ions for 1*i* LDH is greater than for 2*i*. Thus, the Langmuir model indicates a higher sorption efficiency of 1*i* LDH, which is consistent with the data represented in Table 2.

The structure, and therefore the sorption properties in relation to chromate ions for LDHs produced by the classical method (1*i* and 1*ii*) and LDHs produced under the influence of ultrasound and pressure (2*i* and 2*ii*) differ.

Chromate ion has a greater affinity for LDHs of 1*i* and 1*ii* types, which may be interesting for the creation of purification systems. The lower affinity of the chromate ion for LDHs of 2*i* and 2*ii* types may be useful for the development of delivery systems and oxidative microoperators, where both the sorption of the chromate ion and its release, i. e., desorption are necessary. Thus, both LDH types are of interest from a practical point of view.

CONCLUSIONS

1. Ultrasound in combination with high pressure intensifies the interaction of magnesium (II) and iron (III) nitrates with alkali, which can be used successfully to produce layered double hydroxides (LDH).

2. The use of ultrasound in combination with increased pressure allows increasing the crystallinity of the resulting LDHs.

3. The resulting LDHs are sorbents of chromate ions. The sorption properties of LDH produced by the conventional method are more pronounced than those of LDH obtained under the influence of ultrasound and pressure.

4. For LDHs produced by the conventional method, sorption is better described by the Freundlich model, and for LDHs produced under the influence of ultrasound and pressure – by the Langmuir model.

5. The experimental results indicate that when using the same forms of hydroxide as sorbents, for the same time, sorption improves when exposing the system to ultrasound, and even more when ultrasound is applied in combination with increased hydrostatic pressure.

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Сорбционные свойства слоистых двойных гидроксидов, полученных при ультразвуковом воздействии

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Аннотация: Слоистые двойные гидроксиды (СДГ) можно отнести к классу перспективных материалов благодаря простоте синтеза, а также обширной сфере их применения. Однако процесс синтеза СДГ в зависимости от их химического состава может занимать от десятков часов до нескольких суток. Ранее было установлено, что воздействие ультразвуком в процессе получения СДГ значительно сокращает время синтеза, а полученные таким способом СДГ интересны в отношении изучения их физико-химических свойств, а также сорбционной способности. В работе получены Mg/Fe СДГ в нитратной форме традиционным методом, а также при совместном действии ультразвука и повышенного гидростатического давления. Полученные образцы охарактеризованы с помощью комплекса физико-химических методов анализа, включающих сканирующую электронную микроскопию (СЭМ), инфракрасную спектроскопию (ИК), рентгенофазовый анализ (РФА), термогравиметрический анализ (ТГА) с дифференциальной сканирующей калориметрией (ДСК). Проведены эксперименты по исследованию сорбционной способности полученных образцов Fe/Mg СДГ по отношению к хромат-ионам в нормальных условиях, а также при действии ультразвука, в т. ч. в сочетании с повышенным гидростатическим давлением. На фотоэлектрическом фотометре были получены и проанализированы данные с количественными значениями процесса сорбции. Данные, полученные в ходе комплексного анализа готового продукта, указывают на то, что синтезированный материал является Mg/Fe слоистым двойным гидроксидом. При проведении рентгенофазового анализа выявлено, что синтез СДГ с применением ультразвука и давления повышает степень кристалличности конечного продукта. Установлено, что сорбционные свойства СДГ, полученных традиционным способом, и СДГ, полученных под действием ультразвука и давления, отличаются. У Mg/Fe СДГ, синтезированных традиционным методом, сорбция хромата протекает лучше, чем у образцов, синтезированных при помощи ультразвуковой обработки в сочетании с повышенным гидростатическим давлением. Показано, что процесс сорбции исследованных образцов СДГ описывается разными математическими моделями.

Ключевые слова: слоистые двойные гидроксиды; Mg/Fe; ультразвуковой синтез; сорбционные свойства; хромат-анионы.

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