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SYNTHESIS AND STUDY OF COMPLEX COMPOUNDS BASED ON FERRİC CHLORİDE ($FeCI_3$) REACTIONS WITH AMINO ACIDS

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Abstract: Complex compounds of iron (III) chloride with representatives of aliphatic, aromatic and heterocyclic amino acids were synthesized. Structures of the obtained compounds were presented on the basis of IR-, UV-spectroscopy and by chemical analysis method. The Fe^{+3} complex with glycine was tested as a catalyst in the model reaction of aerobic oxidation of isopropylbenzene (cumene) in the presence of hydrogen peroxide. As a result, it found that this complex exhibits strong catalytic activity in the aerobic oxidation of oil hydrocarbons with hydrogen peroxide. The synthesized complex compounds were also studied for biological activity in living organisms, and it was establishedthat they have antibacterial, antiviral properties, as well as psychotropic, sedative and antidepressant effects.

***Keywords**: complex compounds, crystalline hydrate $FeCI_3{\cdot}6H_2O$, glycine, tryptophan, histidine, amino acids, catalysts, biologically active substances.*
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Introduction

Biosynthesis of some organic substances like ferments, vitamins and pigments occurs with the participation of ions of 3-d metals, such as copper, iron, cobalt, nickel, manganese, chromium, vanadium, the mechanism of formation and action of which has not been sufficiently studied. For more detailed understanding of mechanisms of biochemical reactions, it is of great interest to study possible reactions of 3d metals with amino acids as the simplest models of the formation of metal complexes with proteins [1-4].

The structure of α-amino acids allows forming different forms of complex compounds with metal ions [5-8]. The carboxyl group can give nine forms of binding an amino acid molecule to a metal ion, and the presence of an amino group makes it possible to form chelate complexes, and in the presence of other additional donor groups in the side chain, the number of forms increases. Ions of 3d-metals have an optimal ionic radius, and the spatial arrangement of 3d-orbitals allows the formation of a covalent bond with oxygen of COOH– group and with nitrogen of the NH_2-group.

Investigations show that amino acids in aqueous solutions can exist in the form of a bipolar ion which is often called the internal salt, and in the solid state they exist in a molecular form:

$$NH_2{-}R{-}COOH \leftrightarrow H_3^+N{-}R{-}COO^-$$

An intermediate cyclic structure with an intramolecular hydrogen bond is also possible. Amino acids have optical activity, i.e. they are able to rotate the plane of polarized light and can exist in the form of two optical isomers- L (left-handed) and D (right-handed). Almost all natural alpha amino acids have an L-configuration. Exceptions may be D-isomers of glutamic acid, alanine, valine, phenylalanine, leucine and a number of other amino acids.

Amino acids of the D- conformation are included in the composition of some peptide antibiotics, alkaloids, etc., while L-amino acids are included in protein compositions.

The selective oxidation of hydrocarbons with molecular oxygen and hydrogen peroxide as oxidizing agents into target products is currently one of the top-priority areas of catalysis and supposes using metal-complex catalysts. By varying ligand environment at the metallic center of the complex and using different activating agents we can influence the yield of target products of oxidation and thereby control selectivity of the reaction [9-11]. Issues of hydrocarbon oxidation with molecular oxygen and hydrogen peroxide during catalysis with models of biological systems that are capable of implementing the selective introduction of oxygen atoms by C-H bonds of organic molecules is of scientific and practical importance.

Experimental part

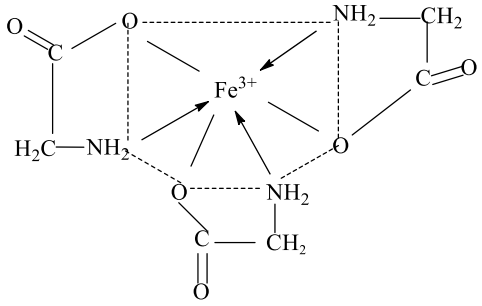
We used α-amino acids - L-glycine (analytical grade), L-tryptophan (analytical grade), L-histidine (analytical grade), $FeCI_3 \cdot 6H_2O$ crystalline hydrate (pure), reactive cumene of 98% purity ("Sigma-Aldrich"), 30% hydrogen peroxide.

The IR spectra of the samples were recorded on spectrometer «Nicolet İS10» from Thermo Scientific (USA) while the UV spectroscopy of synthesized complexes was recorded on spectrophotometer «UV-1800» from Shimadzu (Japan). Elemental analysis was performed on an analyzer from Carlo Erba, iron was determined photometrically, chlorine was determined potentiometrically.

On the basis of experimental data and literature sources, the optimal conditions for the reactions of formation of complex compounds of ferric chloride ($FeCI_3$) with α-amino acids (glycine, tryptophan and histidine) are established. Their structure was established using IR, UV spectroscopy and chemical analysis. The complex $FeCl_3 \cdot 6H_2O$ salt with tryptophan was obtained in an aqueous methanol medium at a ratio of initial components of 1: 3 for 5 hours and a temperature of 35-40^{0}C. The resulting solution was evaporated; the precipitated crystals filtered off on a Hirsch funnel, washed with methanol, acetone and dried to a constant weight at a temperature of 40^{0}C. The reaction product yield was 72.0%. Precipitated crystals of the complex of ferric chloride ($FeCI_3$) with tryptophan were black-violet. Similarly, complexes of ferric chloride with glycine and histidine with the yields of 73% and 78%, respectively, were synthesized. Precipitated crystals of the complex of ferric chloride with glycine were dark yellow, and with histidine a brown color. All synthesized complexes of ferric with the indicated proteins are not soluble in alcohols, benzene, toluene, and acetone, but are well soluble in water at a room temperature. The resulting complexes are sufficiently stable against light and air.

Results and discussion

The compositions and structures of the obtained complexes were established on the basis of IR-, UV-spectroscopy and chemical analysis. The structure of the complex Fe^{+3} based on glycine is presented below:



In the normal state the glycine molecule is in the form of zwitter-ion (NH_3^+–CH_2–COO^-) and therefore, adsorption bands of NH_3^+ and COO^- ions are observed in the IR-spectrum of glycine : ν_{NH3+} = 3099 cm^{-1}; σ_{NH3+} = 1633 cm^{-1} and 1574 cm^{-1}. During complexation under the impact of the fields of central ions, the form of the glycine zwitter-ion proceeds into the amino acid form and glycine enters the internal sphere of the complex as an adduct that is proved by the absorption bands of carboxyl and amino groups. In the IR-spectra the wide absorption band in the range of 2500-3200 cm^{-1} refers to amino acid form $\nu_{OH(COOH)}$, and the absorption band related to valence vibrations of carbonyl fragment is observed at 1751 cm^{-1} and 1761 cm^{-1}.

The reaction of obtaining the complex $FeCI_3 \cdot 6H_2O$ salt with tryptophan can be presented by the following scheme:

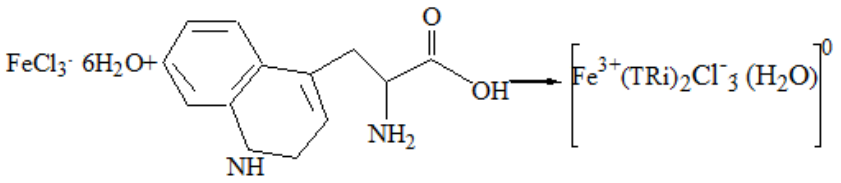


Fig. 1 shows IR-spectrum of the complex $FeCI_3 \cdot 6H_2O$ salt with tryptophan.

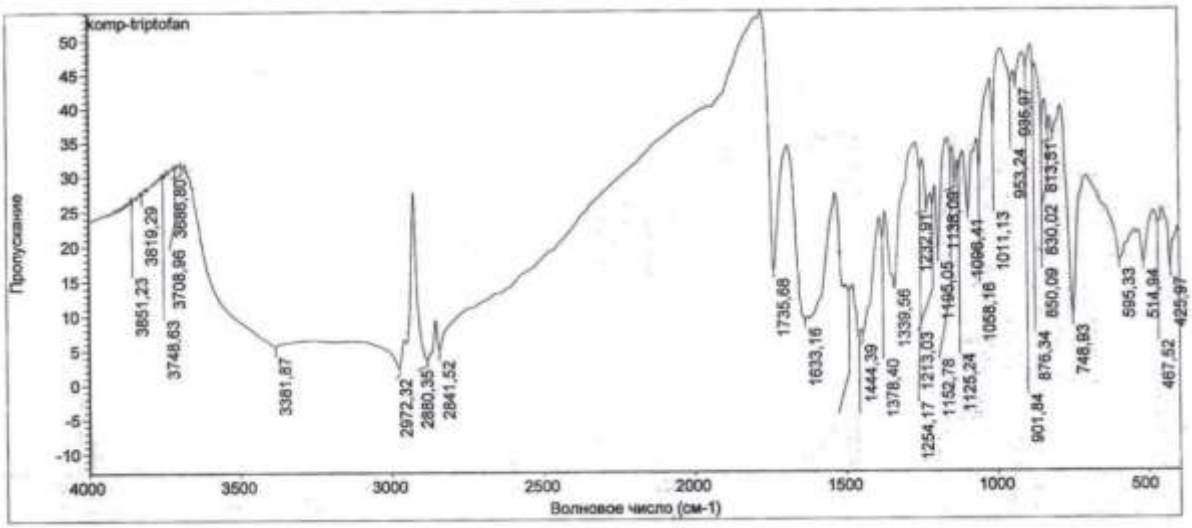


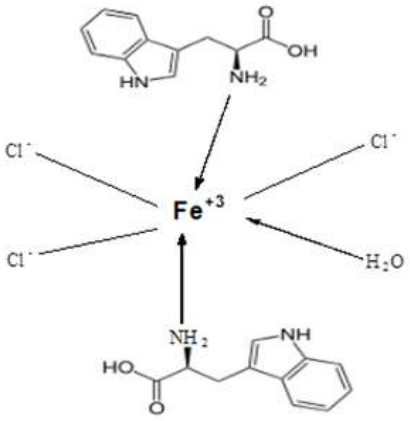
Fig. 1. IR spectrum of the complex $FeCI_3 \cdot 6H_2O$ salt with tryptophan

The structure of the obtained tryptophan complex of ferric chloride was confirmed by IR, UV spectroscopy and chemical analysis. On the IR spectrum in the region of 3381.87 cm^{-1}, an

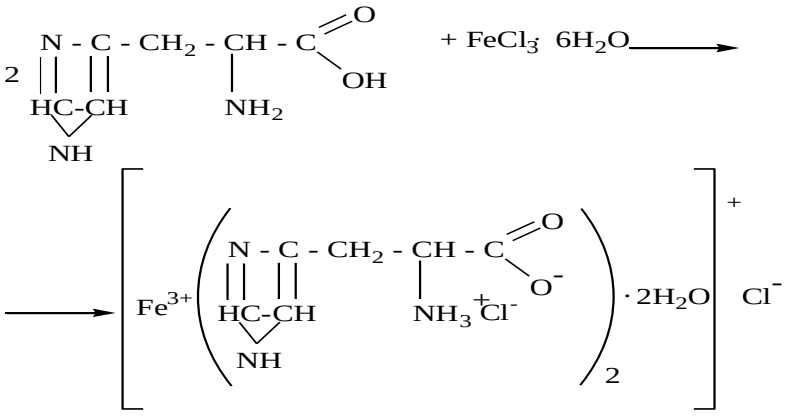
elongated absorption band is observed which confirmed the presence of a water molecule in the complex. This is related to a water molecule included into coordination.

According to the UV spectra, the absorption bands of 196.5 nm, 218.5 nm and 278.5 nm correspond to the absorption bands of the benzene ring of the tryptophan molecule. The absorption bands at 311 nm, 320 nm and 342 nm are characterized by an electronic ligand-metal transition. Note that d-d transitions are not observed in the visible region of UV spectroscopy. This result coincides with the data obtained from IR-spectroscopy. Thus, based on the data of IR spectroscopy, it was proved that in the internal sphere of synthesized complex tryptophan molecules are absorbed as adduct-ligands.

The structure of the obtained complex of ferric chloride with tryptophan is shown below:

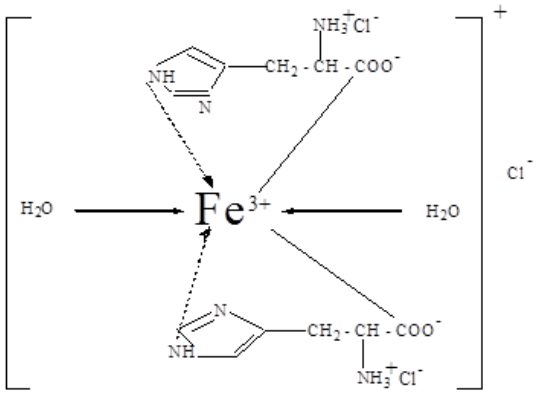


The reaction of obtaining the complex salt $FeCI_3 \cdot 6H_2O$ with histidine can be described by the following scheme:



The intensity of the absorption bands of coordinated water molecules of crystalline hydrate in the IR spectrum of the obtained histidine complex of ferric chloride with ν_{OH} = 3405.56 cm^{-1}, σ_{OH} = 2007.57 cm^{-1} corresponds to two water molecules that were proven thermogravimetrically. The absorption bands of the deformation vibrations of the H_2O molecules entering the complex are observed at 1633.53 cm^{-1}, and ν_{NH} = 3157.62 cm^{-1} and 3072.71 cm^{-1} belong to NH_3^+ ions. And also absorption bands of Cl^- ions are observed at 630.58 cm-1 and absorption bands of COO^- at 1633.53 cm^{-1} and 1309 cm^{-1}. Absorption bands at $\nu_{C=O}$ = 1700-1760 cm^{-1} related to the carboxyl group (COOH) are absent.

The structure of the obtained complex of ferric chloride with histidine is presented below:



Results of chemical analysis confirmed the individuality and composition of the obtained complex compounds (table 1).

Table 1. Results of chemical analysis of Fe^{+3} complexes

Complex	Calculated / Found, %			
	Fe	N	Cl	H_2O
$Fe(NH_2CH_2OCO)_3$	20.13 20.36	15.09 14.88	–	–
$[Fe(C_{11}H_{12}N_2O_2)_2Cl_3 \cdot H_2O]$ *	9.51 9.73	9.51 9.34	18.08 18.24	3.05 3.21
$[Fe(C_6H_9N_3O_2)_2 \cdot 2Cl \cdot 2H_2O]Cl$	15.83 15.97	11.88 11.70	30.11 30.21	10.18 10.32

* Intra-sphere chlorine is not determined argentometrically

The obtained complexes were tested as catalysts in the model reaction of aerobic oxidation of isopropylbenzene (cumene) in the presence of hydrogen peroxide.

Fig. 2 shows the kinetic dependence of oxygen absorption during the oxidation of cumene in the presence of the complex Fe^{+3} salt with glycine.

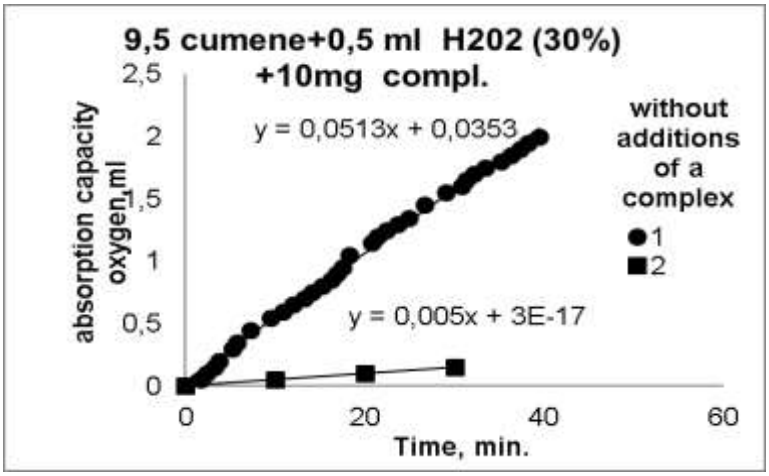


Fig.2. Kinetic dependence of oxygen absorption during aerobic oxidation of cumene in the presence of hydrogen peroxide and complex Fe^{+3} salt with glycine (Fe^{+3}@ $(NH_2CH_2OCO)_3$). The volume of the reaction mixture is 10 cm^3, the temperature is 373K, PO_2 = 20 kPa.

Currently available information about the relationship between the chemical structure of a substance and the pharmacological action allows purposefully synthesis of medicines.

The synthesized complex compounds of $FeCI_3 \cdot 6H_2O$ salts with the examined amino acids were tested for biological activity in laboratory mice and rats (Table 2).

Table 2. Results of initial tests of complex compounds of $FeCI_3 \cdot 6H_2O$ salts with glycine, tryptophan and histidine

№	Name of complex	Biological activity		
		Antiviral	Antibacterial	Psychotropic
1.	$FeCI_3 \cdot 6H_2O$ with glycine $Fe(NH_2CH_2OCO)_3$	Not detected	Mild effect against golden staphylococcus (100 mcg / ml)	Not detected
2.	$FeCI_3 \cdot 6H_2O$ with tryptophan $[Fe(C_{11}H_{12}N_2O_2)_2Cl_3 \cdot H_2O]$	Activity against rotavirus	Not detected	Antidepressant sedative effect (15-20 mg / kg)
3.	$FeCI_3 \cdot 6H_2O$ with histidine $[Fe(C_6H_9N_3O_2)_2 2Cl \cdot 2H_2O]Cl$	Weak activity against rotavirus	Mild effect against golden staphylococcus (100 mcg / ml)	Sedative effect at a dose of 15-20 mg / kg

As can be seen from Table 2, the obtained complex compounds exhibit antiviral and antibacterial properties, as well as sedative and antidepressant effects (psychotropic activity).

Conclusions

1. The complex compounds of $FeCI_3 \cdot 6H_2O$ salts with glycine, tryptophan and histidine were synthesized. Based on IR, UV spectroscopy and chemical analysis, the structures of the obtained compounds were presented.
2. It revealed that the Cl– ion in the $FeCI_3 \cdot 6H_2O$ complex with glycine and histidine is in the external sphere while in the $FeCI_3 \cdot 6H_2O$ complex with tryptophan it is bound to the Fe^{+3} ion in the internal sphere.
3. The $Fe^{+3}@(NH_2CH_2OCO)_3$ complex exhibits strong catalytic activity during aerobic oxidation of cumene in the presence of H_2O_2
4. The synthesized complex compounds of $FeCI_3 \cdot 6H_2O$ salts with glycine, tryptophan and histidine possess biologically active properties.

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DƏMİR (III) XLORİDİN AMİNTURŞULARLA REAKSİYALARI ƏSASINDA KOMPLEKS BİRLƏŞMƏLƏRİN SİNTEZİ VƏ TƏDQİQİ

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Alifatik, aromatik və heterosiklik aminturşularının nümayəndələri ilə dəmir (ıı) xloridin kompleks birləşmələri sintez edilmişdir. İQ-, UB- və kimyəvi analiz üsulu ilə alınan kompleks birləşmələrin strukturları təqdim olunmuşdur. Glisin ilə Fe^{+3} kompleksi hidrogen peroksidinin iştirakı ilə izopropilbenzolun (kumolun) model reaksiyasında aerobik oksidləşməsində katalizator kimi sınaqdan keçirilmişdir, nəticədə bu kompleks hidrogen peroksidlə neft karbohidrogenlərinin aerob oksidləşməsi zamanı güclü katalitik aktivliyini nümayiş etdirdiyi müəyyən edilmişdir. $FeCI_3 \cdot 6H_2O$ duzlarının yuxarıda qeyd olunan alifatik, aromatik və heterosiklik aminturşuları ilə sintez olunmuş kompleks birləşmələrinin canlı orqanizmlərə bioloji aktivliyinin təsiri öyrənilmişdir və onların antibakterial, antivirus xüsusiyyətlərinə, habelə psixotrop, sedativ və antidepressiv effektə malik olması müəyyən edilmişdir.

Açar sözlər: *kompleks birləşmələri, $FeCI_3 \cdot 6H_2O$ kristalhidratı, glisin, triptofan, histidin, aminturşuları, katalizatorlar, bioloji aktiv maddələr.*

СИНТЕЗ И ИССЛЕДОВАНИЕ КОМПЛЕКСНЫХ СОЕДИНЕНИЙ НА ОСНОВЕ РЕАКЦИЙ ХЛОРИДА ЖЕЛЕЗА(III) С АМИНОКИСЛОТАМИ

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Синтезированы комплексные соединения соли хлорида железа (III) с представителями алифатических, ароматических и гетероциклических аминокислот. На основе ИК-, УФ-спектроскопии и методом химического анализа представлены структуры полученных комплексных соединений. Комплекс Fe^{+3} с глицином был испытан в качестве катализатора в модельной реакции аэробного окисления изопропилбензола (кумола) в присутствии пероксида водорода, в результате чего было установлено, что данный комплекс проявляет сильную каталитическую активность при аэробном окислении углеводородов нефти пероксидом водорода. Синтезированные комплексные соединения были исследованы также на биологическую активность на живых организмах и установлено, что они обладают антибактериальными, антивирусными свойствами, а также психотропным, седативным и антидепрессивным эффектом.

Ключевые слова: *комплексные соединения, кристаллогидрат $FeCl_3 \cdot 6H_2O$, глицин, триптофан, гистидин, аминокислоты, катализаторы, биологически активные вещества.*