

THE COMPLEX USING OF THE ESR, THEORETICAL CONFORMATIONAL ANALYSIS AND QUANTUM CHEMISTRY METHODS AT THE 2,03 COMPLEXES STRUCTURE STUDY

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On the basis of the molecular model the spatial structure of iron protoxide dinitrosyl complexes with cysteine was investigated by the methods of CNDO/2 and atom-atomic potential functions. It was shown that these complexes formed in the animal tissues and plant leaves give an ESR signal with $g_{av} \sim 2,03$ (so called 2,03 complexes) and have distorted octahedral structure with two water molecules.

INTRODUCTION

According to the modern ideas [1-3] the endogenous compounds including into nitrogen oxide (NO) and weakly-bounded form of iron are capable participate in the various physiological processes into organism such as vazodilatation, aggregation of trombocytes, regulation of arterial pressure. They are formed paramagnetic centers which characterized by an ESR signal with $g_{av} \sim 2,03$ and may be identified as 2,03 complexes according to the average value of the g -factor. These complexes including into two nitrogen oxide molecules and two paired RS^- groups of proteins are represented low spin mononuclear complexes ($S=1/2$) and can be consider as only form of coexistence of most important intracellular components – loosely bound form of nonhaem iron and nitrogen oxide (Fig.1). The reasons

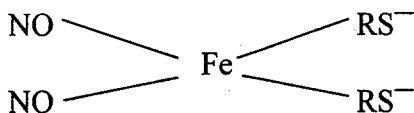


Fig. 1. The model of 2,03 complex structure.

of appears in animal tissues of two types of 2,03 complexes was considered by the method of ESR. The first of complexes (Fig.2a) was recorded in yeast's by the using of the X-range ESR radiospectrometer and characterized by an ESR signal with axial symmetrical tensor of the g -factor ($g_{\perp} = 2,037$, $g_{\parallel} = 2,012$). This ESR signal was identical to those observed for the iron protoxide dinitrosyl complexes with SH-consisting amino acid-cysteine that may be considered as the compound modeling the 2,03 complexes in animal tissues. The second type of ESR signal formed in mouse liver in vivo unlike the first was characterized by the "shoulder" in the central part of the signal (Fig.2b) which after using the radiospectrometer of Q-range transformed into clearly expressed singlet component (Fig.2c). The observed spectra of ESR signal has three main values of the g -factor: $g_1 = 2,037$, $g_2 = 2,03$, $g_3 = 2,012$ which usually are characteristic for the paramagnetic centers with rhombical symmetry. It was shown that there was low molecular compound in the intracellular environment of animal livers influenced on the 2,03 complexes structure formed in it. This influence leads to the lower of the symmetry of this complexes ESR signal's tensor of the g -factor. The 2,03 complexes localized on the external side of liver cells or in the other organs were characterized by the

tensor of the g -factor of the ESR signal with the axial symmetry.

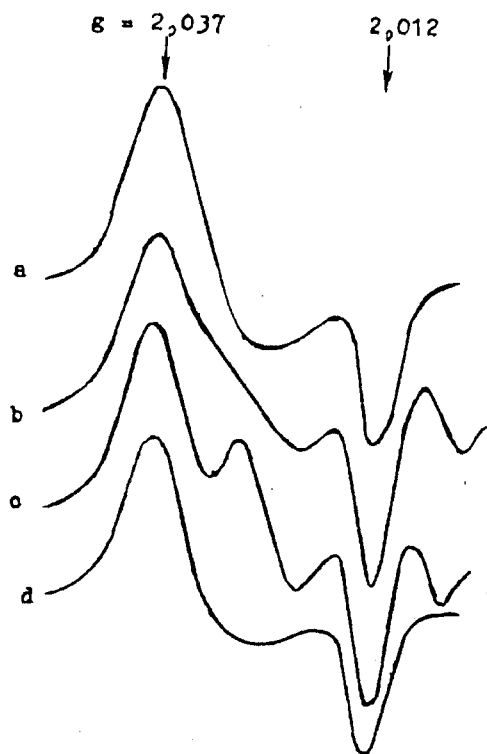


Fig. 2. The 2,03 signal of dinitrosyl iron complexes with cysteine (a, d) and in mouse liver in vivo (b, c). The recording was made at 77 K, (a, b) – with radiospectrometer ESR - 21PC (X-range), (c, d) – with radiospectrometer "Varian E401" (Q-range).

At present there is no clear idea on the spatial structure of iron protoxide dinitrosyl complexes with cysteine (IPDCC). The axial symmetry of the ESR signal's g -factory testifies the high spatial symmetry of the complexes that are close to the tetragonal, trigonal or tetrahedral one. Neither is the fact excluded that IPDCC beside two nitrosyl ligands and two thiol groups of cysteine residues contains one or two solvent molecules as well as two water molecules which do not appear in the ESR-spectrum. However, it is impossible to make a choice in favor of some concrete structure of 2,03 complexes now since the existing information based on the results of study of the compounds up to the present time only indicates to what extent the possible types of the structure correspond to the parameters of their ESR-signal while X-Ray data of these compounds are absent. Therefore, the present paper

is voted to the study of electron and conformational aspects of IPDCC stabilization by means of quantum chemistry and theoretical conformational analysis methods, data beyond the possibilities of previously used experimental procedures for the study of such complexes.

CALCULATIONS

For calculation we used the IPDCC model suggested by the results of ESR spectra analysis in which a ferrous atom is coordinated by two nitrosyl groups and two sulfur atoms of the cysteine's thiol groups. In order to define the optimal orientation of ligands in the spatial structure of complexes by means of theoretical conformational analysis the number of sterically allowable conformations of the complex are determined. The conformational potential energy of molecule is given as a sum of independent contributions of non-valent, electrostatic, torsional interactions and energy of hydrogen bonding. The global potential energy is defined by the minimization procedure and fully optimized minimum energy paths were served as standards for the comparison of the potential obtained with other methods. The calculation of the electron structure of the complex was realized by CNDO/2 semiempirical method by determining the full molecular energy of the complex as a function of bond length, valence and dihedral angles. The calculation was realized in the extended s, p, d-basis using the standard parameterization as described in [4].

RESULTS AND DISCUSSION

According to the calculation results dinitrosyl non-heme iron complex is characterized by deformation of the plane-

square orientation of ligands in the complex due to the drop of one of the sulfur atoms out of the assumed quadratic. The obtained structure is characterized by a nonequivalent distribution of electron density between nitrosyl and thiol groups of ligands. The calculation of dissociation energy of nitrosyl groups has demonstrated that they are different in absolute value, thus proving, as in the case of the tetrahedral structure, the preference of dissociation of NO-groups with total negative charge. Thus the obtained results prevent the unambiguous choice between IPDCC structures with distorted tetrahedral and distorted quadratic coordination of the central atom in relative to two nitrosyl groups and two sulfur atoms of thiol groups in cysteine proving the nonequivalence of these ligands in complex and explaining the contradiction which appears while interpreting the obtained experimental results based on different approximations. One of the factors which do not appear in the ESR spectrum but the influence on the 2,03 complexes symmetry is the inclusion of one or two water molecules into 2,03 complexes. It was obviously from the results of calculation that the consecutive addition of first and then the second water molecule are the factor which stabilized the structure of dinitrosyl iron complexes without any effect on its geometry. According to the results of calculation the dinitrosyl iron complexes are the six-coordinated complexes distorted octahedral structure of which is characterized by the non-equivalency of electron density distribution at Fe-NO bonds. The obtained results based on the ESR, theoretical conformational analysis and quantum chemistry methods make it possible assert that the study of the mechanism and conditions of forming six-coordinated dinitrosyl iron complexes can be considered as a model of intracellular environment influencing on 2,03 complexes structure formed in animal tissues.

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EPR, NƏZƏRİ KONFORMASIYA ANALİZİ VƏ KVANT KİMYASI ÜSULLARININ 2,03 KOMPLEKSİNİN STRUKTUR TƏDQIQINDƏ BİRGƏ İSTİFADƏ EDİLMƏSİ

Atom-atom potensial funksiyalar və CNDO/2 üsulları ilə dəmir dinitrozil kompleksinin sisteminlə fəza quruluşu öyrənilmişdir. Göstərilmişdir ki, heyvan və ali bitkilərin hüceyrələrində əmələ gələn bu komplekslər YPR signalı ilə $\sigma_{\text{ep}} \sim 2,03$ (2,03 kompleksi) xarakterizə olunur və 2 su molekulunun təhrif edilmiş oktaedrik strukturu ilə təsvir edilir.

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СОВМЕСТНОЕ ИСПОЛЬЗОВАНИЕ МЕТОДОВ ЭПР, ТЕОРЕТИЧЕСКОГО КОНФОРМАЦИОННОГО АНАЛИЗА И КВАНТОВОЙ ХИМИИ В ИССЛЕДОВАНИЯХ СТРУКТУРЫ КОМПЛЕКСОВ 2,03

Методами атом-атомных потенциальных функций и CNDO/2 изучено пространственное строение динитрозильных комплексов железа с цистеином. Показано, что эти комплексы, образующиеся в тканях животных и листьях высших растений, характеризуются сигналом ЭПР с $\sigma_{\text{ep}} \sim 2,03$ (комплексы 2,03) и представлены искаженной октаэдрической структурой с двумя молекулами воды.