

QUANTUM-CHEMICAL INVESTIGATION OF THE MECHANISM OF EUGENOL AND ISOEUGENOL EPOXIDATION BY PERACETIC ACID

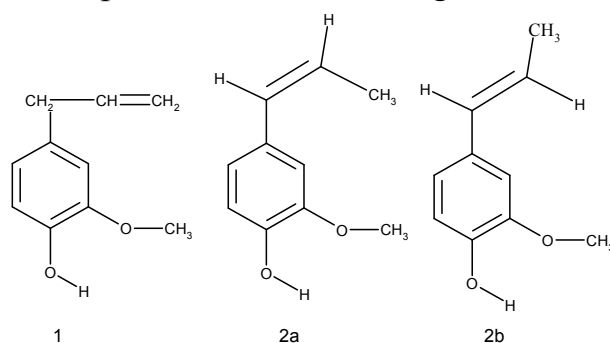
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It is well-known that terpenoids such as eugenol and isoeugenol possess a broad spectrum of biological activity. Thus, the most valuable component of clove oil is eugenol itself. This compound is responsible for a specific flavor, which is associated with a number of medicinal properties. Clove oil has inherent analgesic, spasmolytic, antimicrobial, diaphoretic and diuretic action. Eugenol is used for the production of perfume compositions, such as fragrances for tobacco, as well as for isoeugenol synthesis. It is part of painkillers, antiseptic and biocidal agents. Clove oil as eugenol itself, has an anti-inflammatory effect and is used in dentistry, with pulpitis, caries, periodontitis, lesions of the oral mucosa. Eugenol's isomer (isoeugenol) is also found in ether oils. Clove oil contains mostly *cis*-isoeugenol, while basil and coriander oils contain *trans*-isomer. We have performed a quantum chemical study of the reaction mechanism for the epoxidation of three isomers – eugenol (**1**) and *cis*- and *trans*-isoeugenols (**2a**, **2b**) by peracetic acid (also known as peroxyacetic acid, or PAA). Density functional theory has been used for calculations at UBH&HLYP/6-31G (d) level. This method allows to correctly describe the structure of diradicals and is cost-effective enough for investigation of complex organic compounds and reactions. It has been shown experimentally that the rate constant for the epoxidation of isoeugenol by PAA is 5 times higher if compared to its isomer – eugenol.



As could be seen from Table 1, the values of activation barriers for the epoxidation of *cis* and *trans* forms of isoeugenol are about 20 kJ/mol lower if compared to eugenol epoxidation, which is consistent with experimental data. The transition state for eugenol epoxidation characterizes rather a synchronous process where C-O bond lengths of the forming epoxide cycle have close values. It is important to note that this structure has a closed electron shell, thus, in contrast to other olefins epoxidation

reactions, not showing biradical character of transition state. According to calculations, the activation barriers for epoxidation of *cis* and *trans* forms of isoeugenol have similar values, indicating a negligible effect of its structure on reactivity. Values of geometrical parameters and spin density on the corresponding atoms for transition states (**TS2a**, **TS2b**) are also closet to each other. As shown in Fig. 1, transition states (**TS2a**, **TS2b**) are close to the planar nature (see $C_\alpha C_\beta OH$ angles), and asymmetric with a significant advantage in the formation of $C_\alpha-O_\alpha$ bond over $C_\beta-O_\alpha$. Analysis of the wave function of the transition states (**TS2a**, **TS2b**) shows their biradical nature. The largest spin density localized on C_β and O_β atoms. Partial delocalization of spin density at the *ortho*- and *para*- carbon atoms observed due to conjugation of olefin fragment with benzene ring.

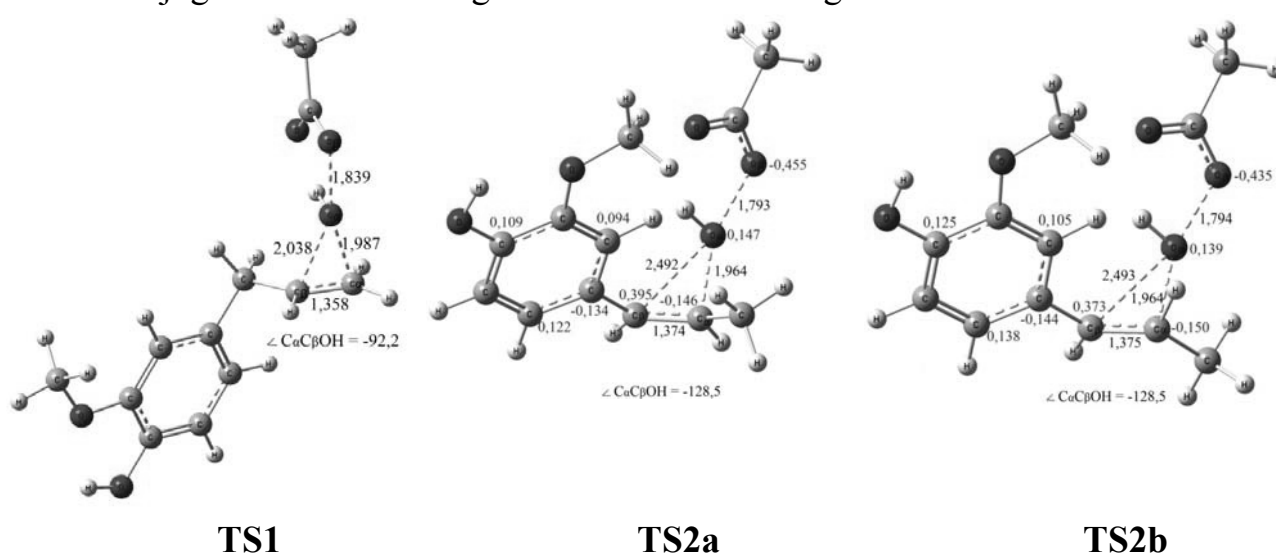


Figure 1. Structure, selected geometrical parameters (printed in black, Å, deg.) and values of spin density on atoms (printed in blue) of (**TS1**, **TS2a**, **TS2b**)

Table 1 – Values of activation parameters for eugenol (**1**) and isoeugenols (**2a**, **2b**) epoxidation by PAA, calculated at UBH&HLYP/6-31G(d) level of theory

Compound	$\Delta H_{\text{act.}}$, kJ/mol	$\Delta G_{\text{act.}}$, kJ/mol
1	122.39	137.37
2a	101.43	117.18
2b	101.29	112.40

Thus, the obtained results reveal in the following concluded: the ratio of activation energy for interaction of eugenol and isoeugenols with peroxyacetic acid shows higher reactivity of isoeugenols. The results are in line with experimental data confirming the correctness of UBH&HLYP/6-31G (d) approach which could be also used for investigation of the regio-chemical particularities of epoxidation of alkenes containing two or more double C=C bonds, such as terpenoids.

*Research has been conducted under supervision of Prof. S.I. *Okovity*¹ and Prof. M.Ye. *Blazheyskiy*²