

# Interpretation of substituent effect of nitro derivatives in selected cyclic systems based on quantum chemistry methods

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## Summary

This doctoral thesis focuses on the studies of substituent effect of the nitro group in cyclic systems: benzene, cyclohexa-1,3-diene and bicyclo[2.2.2]octane. The results are presented as a series of articles where important issues were discussed related to substituent effect on electronic properties, including aromaticity in the analyzed nitro derivatives. To investigate the substituent effect, various theoretical approaches, based on physically defined terms that use quantum-chemistry methods, have been used.

Chapter 1 gives an overview of the current state of research in the field. Chapter 2 describes the computational methods and parameters applied to quantitative investigation of substituent effect's influence on the electronic properties of the studied systems. Chapter 3 provides a commentary to the articles which document this doctoral dissertation and are collected at the end of the thesis.

Studies on electronic properties of the nitro group are associated with its strongly electron-attracting character due to strong inductive and resonance activities. Application of SE descriptors based on quantum chemistry models: Substituent Effect Stabilization Energy, (SESE), Charge of Substituent Active Region (cSAR) and *pi/sigma* Electron Donor/Acceptor indices (pEDA/sEDA) allows a new perspective on the substituent effect of the nitro group, traditionally described by substituent Hammett constants. The subject of the following dissertation is a description of SE for a wide range of *meta* and *para*-substituted systems: benzene, bicyclo[2.2.2]octane, cyclohexa-1,3-diene, in which the NO<sub>2</sub> group is treated as a "reaction site". The SE descriptors used allow to characterize quantitatively the strength of interactions between the nitro group and the substituent, independent of the nature of transmitter to which they are attached. The novelty of the analysis presented here is its description of SE by the population of electrons in *sigma* and *pi* orbitals for both the nitro group and the ring for derivatives of *para*- and *meta*-substituted nitrobenzene and *para*-type cyclohexadi-1,3-ene systems. It allows to describe the efficiency of electron flow in the system. An important aspect of this research is showing that descriptors of SE used for the analyzed nitro-derivatives may also be applied to characterize the strength of impact of substituent in water (PCM model - Polarizable Continuum Model).

Studies of SE presented in this work include: the influence of substituent X on electronic properties of the NO<sub>2</sub> group (classical substituent effect), the impact of the NO<sub>2</sub> group on electronic properties of substituent X (reverse substituent effect), inductive and resonance effects of nitro groups, changes in the *pi* and *sigma* electron structure of transmitter R and NO<sub>2</sub> groups and solvent effect on the strength of these interactions.

The presented results can form the basis for applying the above-mentioned models in other areas of research related to the substituent effect on various properties of a system, such as biological systems (DNA and RNA nitrogenous bases). Furthermore, the obtained results may be a starting point for further research into applications of nitro compounds in various studies in the field of organic and bioorganic chemistry (e.g. in the design of molecules with desired

properties, like drugs, pesticides, cosmetics), or in quantitative structure-activity analyses (QSAR).