

Editorial

Non-Covalent Catalysts

Alexander S. Novikov^{1,2} 

¹ Institute of Chemistry, Saint Petersburg State University, Universitetskaya Nab., 7/9, 199034 St. Petersburg, Russia; a.s.novikov@spbu.ru or novikov@itmo.ru

² Infochemistry Scientific Center, ITMO University, Kronverksky Pr., 49, bldg. A, 197101 St. Petersburg, Russia

The elementary stages of chemical reactions (including catalytic ones) are caused by such weak inter- and intramolecular contacts as hydrogen, halogen, chalcogen, and tetrel bonds as well as stacking (and other π -system-involved) interactions. The aim of this Special Issue of *Catalysts*, entitled “Non-Covalent Catalysts”, is to address the most recent progress in the rapidly growing field of non-covalent interactions in catalysis. Both experimental and theoretical studies, as well as fundamental and applied research, and any forms of manuscripts (for example, reviews, mini-reviews, full papers, short communications, technical notes, and highlights), were considered for inclusion. This Special Issue addresses the following topics: the experimental studies of non-covalent interactions in catalysis; the theoretical modeling of supramolecular systems in catalytic processes; the application of machine learning and artificial intelligence in the studies of non-covalent interactions in catalysis; the development of catalysts via non-covalent interactions; databases of non-covalent catalysts; and analytical techniques for the detection of non-covalent interactions in complex chemical systems. Scholars in these areas were encouraged to contribute to our Special Issue.

In this Editorial, I would like to briefly highlight the main successes of our research group in the field of fundamental studies of non-covalent interactions in catalysis over the past 3 years. In [1], based upon the experimentally obtained kinetic data on the iodonium salt catalyzed nucleophilic addition of isocyanide to imine leading to imidazopyridine species, a reliable model was established for density functional theory (DFT) calculations. It was shown that the preassociation of the catalysts with the reaction species might significantly affect the total energy profile of the reaction obtained using DFT. The associates of the organocatalysts featuring the solvent molecules ligated to their σ -holes should be used as a starting point for calculations. Considering these reaction steps during the calculations leads to significantly more reliable theoretical results, which can be applied either for the prediction of the catalytic activity of yet untested species or the justification of the catalytic paths based upon the experimental kinetic data as well. In [2], a theoretical study shed light on the relative catalytic activity of pnictonium, chalconium, and halonium salts in reactions involving the elimination of chloride and electrophilic activation of a carbonyl group. DFT calculations revealed that for cationic aromatic onium salts, the values of the electrostatic potential on heteroatom σ -holes gradually increased from pnictonium to halogen-containing species. The higher values of the potential on the halogen atoms of halonium salts resulted in the overall higher catalytic activity of these species, but in the case of pnictonium and chalconium cations, weak interactions from the side groups provided an additional stabilization effect on the reaction transition states. Based on quantum-chemical calculations, the catalytic activity of phosphonium(V) and arsenonium(V) salts was too low to obtain effective non-covalent organocatalytic compounds, whereas stibonium(V), telluronium(IV), and iodonium(III) salts exhibited higher potential in their application as non-covalent organocatalysts. In [3], sulfonium and selenonium salts, represented by *S*-aryl dibenzothiophenium and *Se*-aryl dibenzoselenophenium triflates, were found to exhibit remarkable catalytic activity in the Groebke–Blackburn–Bienaymé reaction model. Kinetic



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analysis and DFT calculations indicated that their catalytic effect was induced by the ligation of the reaction substrates to the σ -holes on the S or Se atom of the cations. The experimental data indicated that although 10-fold excess of the chloride totally inhibited the catalytic activity of the sulfonium salts, the selenonium salt remained catalytically active, which can be explained by the experimentally found lower binding constant of the selenonium derivative to chloride in comparison with the sulfonium analogue. In the reaction model, both types of salts exhibited lower catalytic activity than dibenziodolium species. In [4], DFT computations indicated that cationic and non-charged xenon derivatives should exhibit higher catalytic activity than their iodine-based non-covalent organocatalytic congeners. Perfluorophenyl xenonium(II) was found to have the best balance between catalytic activity and chemical stability for use in organocatalysis. Comparing its catalytic activity with that of isoelectronic perfluoroiodobenzene indicated that the high catalytic activity of cationic non-covalent organocatalysts was predominantly attributed to the electrostatic interactions with the reaction substrates, which caused the polarization of ligated species during the reaction progress. In contrast, the electron transfer and covalent contributions to the bonding between the catalyst and substrate had negligible effects. The dominant effect of electrostatic interactions resulted in a strong negative correlation between the calculated Gibbs free energies of activation for the modeled reactions and the highest potentials of the σ -holes on the central atoms of the catalysts. No such correlation was observed for non-charged catalysts. In [5], it was demonstrated that dibenziodolium and diphenyliodonium triflates displayed high catalytic activity for the multicomponent reaction that led to a series of imidazopyridines. The DFT calculations revealed that both the salts could play the role of hybrid hydrogen- and halogen-bond-donating organocatalysts, which electrophilically activated the carbonyl and imine groups during the reaction process. The *ortho*-H atoms in the vicinal position to the I atom played a dual role: forming additional non-covalent bonds with the ligated substrate and increasing the maximum electrostatic potential on the σ -hole at the iodine atom owing to the effects of polarization. Dibenziodolium triflate exhibited higher catalytic activity, and the results obtained from ^1H nuclear magnetic resonance (NMR) titrations, in conjunction with those from DFT calculations, indicated that this could be explained in terms of the additional energy required for the rotation of the phenyl ring in the diphenyliodonium cation during ligation of the substrate. In [6], the authors carried out the successful application of electrostatic surface potential distribution analysis for evaluating the relative catalytic activity of a series of azolium-based halogen bond donors. A strong correlation ($R^2 > 0.97$) was observed between the positive electrostatic potential of the σ -hole on the halogen atom and the Gibbs free energy of activation of the model reactions (i.e., halogen abstraction and carbonyl activation). The predictive ability of the applied approach was experimentally confirmed. It was also determined that the catalytic activity of azolium-based halogen bond donors was generally governed by the structure of the azolium cycle, whereas the substituents on the heterocycle had a limited impact on the activity. Ultimately, this study highlighted four of the most promising azolium halogen bond donors, which are expected to exhibit high catalytic activity. Finally, in [7], hypervalent iodine(III) derivatives were found to have higher catalytic activity than other aliphatic and aromatic iodine(I)- or bromine(I)-containing substrates for a Knorr-type reaction of N-acetyl hydrazides with acetylacetone to yield N-acyl pyrazoles. The highest activity was observed for dibenziodolium triflate, for which 10 mol% resulted in the generation of N-acyl pyrazole from acyl hydrazide and acetylacetone typically at 50 °C for 3.5–6 h with up to 99% isolated yields. The ^1H NMR titration data and DFT calculations indicated that the catalytic activity of the iodine(III) was caused by its binding with a ketone.

I hope that other authors will follow my initiative, and readers of this Special Issue of *Catalysts* will have the opportunity to get acquainted with the achievements of researchers in this modern topic.

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