Chirality transfer in vibrational optical activity spectra

Research project objectives

Vibrational optical activity methods Vibrational Circular Dichroism (VCD) and Raman Optical Activity (ROA) are spectroscopic techniques sensitive to the chiral molecules only. The achiral compounds are inactive in VCD and ROA. These spectroscopic techniques are promising tools for investigations of the intermolecular interactions. The VCD and ROA spectra are sensitive to the solvent and environment effects as well as conformational changes.

As a result of interaction of a chiral molecule with an achiral one, bands of the latter appear in the VCD spectra. The phenomenon is called "*chirality transfer*" (ChT) or "*induced chirality*" and allows for monitoring the formation and conformation of the intermolecular complexes of chiral molecules. ChT phenomenon was studied in systems in which the dissolved chiral molecule interacted with an achiral solvent. On the other hand, the chirality transfer generator can be a chiral solvent which interacts with an achiral molecule. Such systems have never been studied by the VCD method, yet, the problem was recognized by the Electronic Circular Dichroism (ECD). It seems that the ChT phenomenon in the chiral solvent - achiral molecule system should occur more effectively. Surrounding of the achiral molecule solely by the chiral solvent molecules should favor the formation of the complexes and the VCD ChT bands should be easier manifested. Based on the ChT bands it will be possible to monitor interaction and conformation of the achiral molecules by vibrational optical activity methods.

The aim of the project is a comprehensive computational and experimental study of the VCD chirality transfer phenomenon in the model chiral solvent - achiral molecule systems. While the chirality transfer phenomenon in the VCD spectra is partly recognized there is no literature report on the ChT manifested in the ROA spectroscopy. Probably this is due to technical difficulties but perhaps also because the experimental models used were not optimal. In this context, the prediction of ChT phenomenon in ROA spectra by using the quantum-chemical methods and selection of the best systems for such measurements is an important task of this project. Based on the theoretical prediction new difficult ROA measurements can be planned in future. This is important because the commercially available ROA spectrometers spectral range is between 2000-100 cm^{-1}, where the vibrations sensitive to deformation and dynamics of biological systems occur. Thus, this method is superior to the VCD one (of 2000-800 cm^{-1} spectral range) as it allows for studying systems interesting for biology and medicine.

Research project methodology

In this project combined computational/experimental studies on the chiral solvent - achiral molecule systems are planned. To avoid apparatus artifacts only chiral molecules which have both enantiomers commercially available were chosen. The model systems exhibit different types of donor-acceptor interaction centers and can be stabilized by hydrogen-bonds (HB) or electron-donor-acceptor (EDA) interactions. The 1-phenylethanol, α-methyl-benzylamine and limonene were chosen as the chiral solvents. The achiral compounds selected for the study can be divided into "chemical" and "biological". In the first group there are simple chemical molecules which can either form complexes by a hydrogen-bonded (pyridine and phenol) or by an EDA interaction (benzene, tetracyanoethylene, boron trichloride and hexamethylbenzene). The selected achiral "biological" molecules are: β-alanine (the β-amino acid most commonly occurring in the nature), BTA-1 (neutral form of thioflavin T – a fluorescent probe of misfolded protein aggregates called amyloid) and uracil derivatives (uracil is a component of RNA and some of its derivatives are used in oncology). The interpretation of experimental results will be based on the calculated spectra which will take into account all interacting complex geometries. In addition, based on calculation, the new, effective, systems will be proposed for registration of the chirality transfer bands in the ROA spectra.

Relevance of the project

The project will deepen our knowledge on the intermolecular interactions, methods of their detection, applications of chiroptical vibrational methods and prediction of the VCD and ROA spectra by using quantum-chemical calculations. In the future these studies will contribute to the development of chiroptical methods as tools for measurement systems important for pharmacy and medicine.