Invited Lecture

New trends in Quantum Crystallography: from case studies of disordered structures to archetypes

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Quantum Crystallography (QCr) [1-2] is currently one of the most active research areas in small-molecule crystallography. QCr aims to enhance quantum chemical (QC) computations with experiments, and experiments by information from QC calculations. Starting from 1.) azulene [3], the classical example of a disordered crystal structure, questions arising from studying four selected and peculiar crystal structures and the insight gained will be revisited. Why disorder occurs in azulene is discussed first [4]. The structure of 2.) imipenem monohydrate [5] and its disorder is the next example. Disorder in its crystal structure, although unambiguously characterized initially, gradually disappeared in subsequent measurements. The disappearing disorder in imipenem led to the proposal of 'archetype structure', idealized non-disordered structures consisting of a part of the disordered *and* the non-disordered atoms. In 3.) propionamide (one of many other examples) there is disorder at low temperature, but not at room temperature [6].

Studying the energetics of solid-state phenomena was made more convenient through the molecule-in- cluster (MIC) approach [7]. Maintaining unit-cell parameters, subsequent optimization of the asymmetric unit (ASU) in a fixed cluster environment generated from the ASU by space-group symmetry to convergence is faster and more widely applicable to systems with reduced order than classical computations with periodic boundary conditions. Structure-specific restraints from MIC computation can be used to better model disordered structures in the spirit of QCr: combining restraints from several optimized archetypes significantly improves least-squares refinement of disordered crystal structures [6]. In example 4.) 17-ß oestradiol hemihydrate, there are two competing hydrogen-bond patterns in its average structure, which can both be optimized separately as archetypes, but which can hardly be disentangled from experiment alone: the experimental structure corresponds to an overlay of quantum states with distinct minima separated by energy barriers [8]. Adding energies (namely energy barriers or relative energy differences) to experimental coordinates is the unifying approach taken in all these recent studies.

Ultimately it is not just disordered structures, but several other solid-state phenomena whose conceptualization is facilitated by 'archetype crystal structures' and their energetics. Archetypes bridge the established categories of disorder, polymorphism, solid solutions, special-position and high-*Z'* structures [8], with more conceivable applications like phase transitions and isostructural structures, and this will be discussed in more detail. What is QCr to me in a nutshell? Adding energies to structures.

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I would like to acknowledge H. Moebitz for encouragement and support.