A primary goal of the global electronics industry is the further miniaturization of the transistor, which currently has a size on the order of one micron (one millionth of a meter). Kubiak’s group is studying molecular systems based on inorganic mixed-valence complexes of the type \([\text{Ru}_3\text{O(COO)}_6\text{(CO)(pyridine)}]_2-1,4\text{-pyrazine}\)^{-1} that exhibit a two state switching mechanism like that of a conventional transistor, but on a size scale that is one thousand times smaller, and with a switching time that is one thousand times faster.

The smallest structure known to have device functionality is a single molecule. A common misconception about molecules is that they are static, non-fluctuating arrangements of atoms. In fact, molecules are highly dynamic and can undergo rotational, vibrational, and electronic motions that are extremely fast. Kubiak’s group is harnessing these ultrafast motions in inorganic mixed-valence molecular systems that can transfer an electron between two stable states in less than one picosecond (one trillionth of a second). This switching event can be regulated (gated) by an external chemical or electrical stimulus.

The mixed-valence molecular systems discovered by Kubiak and coworkers are the only molecules, organic or inorganic, that exhibit both bi-stable states (two stable interchangeable states) and one trillion per second switching times. Study of these molecular systems will likely influence and guide broader thought about the specific chemical, physical, and engineering issues that will bring molecular electronic based devices into the mainstream.

Comparison of the architecture, processing speed, and size of a conventional silicon transistor (top left) and a potential molecular electronic device (middle right), the inorganic mixed-valence complex \([\text{Ru}_3\text{O(COO)}_6\text{(CO)(pyridine)}]_2-1,4\text{-pyrazine}\)^{-1}. Images provided by Benjamin Lear, Kubiak Research Group, Department of Chemistry and Biochemistry, University of California, San Diego.
