

Measuring Molecular Parity Nonconservation Using Nuclear-Magnetic-Resonance Spectroscopy

J. Eills,^{1,2} J. W. Blanchard,³ L. Bougas,² M. G. Kozlov,^{4,5} A. Pines,^{6,7} and D. Budker^{2,3,8,9}

¹School of Chemistry and Institute for Life Sciences, University of Southampton, Southampton, United Kingdom

²Johannes Gutenberg-Universität Mainz, 55128 Mainz, Germany

³Helmholtz-Institut Mainz, 55099 Mainz, Germany

⁴Petersburg Nuclear Physics Institute, Gatchina, 188300, Russia

⁵St. Petersburg Electrotechnical University LETI, Professor Popov Street 5, St. Petersburg 197376, Russia

⁶Materials Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA

⁷Department of Chemistry, University of California, Berkeley, California 94720, USA

⁸Department of Physics, University of California, Berkeley, California 94720-7300, USA

⁹Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA

Physical processes mediated by the weak interaction are known to be asymmetric with respect to spatial inversion due to the parity nonconserving (PNC) nature of the weak interaction. The first experimental demonstration of PNC effects was observed previously in β decay of oriented ^{60}Co nuclei [1], and further precision measurement experiments have measured the effect in atomic systems [2]. However, parity violation has not yet been observed in molecular systems, due to the small magnitude of the expected energy shifts and limited spectral resolution. The detection of molecular PNC therefore remains a major experimental challenge.

We have developed a nuclear magnetic resonance (NMR) experiment in which we titrate the chirality (enantiomeric excess) of a solvent and measure the diastereomeric splitting in the spectra of a chiral solute (as in Fig. 1) in order to search for an anomalous offset due to PNC [3]. In the proof-of-principle experiment, we search for PNC in the ^{13}C resonances of small molecules, and use the ^1H resonances, which are insensitive to PNC, as an internal reference. In preliminary experiments, we set a constraint on molecular PNC in ^{13}C chemical shifts at a level of 10^{-5} ppm, as shown in Fig. 2. In this presentation, we will provide a discussion of the current experiment and important considerations for future searches for molecular PNC using NMR spectroscopy.

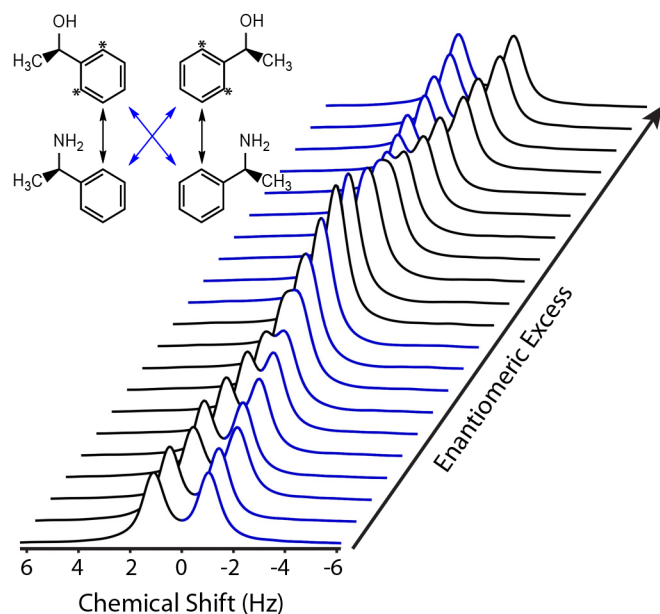


Fig. 1. Stacked ^{13}C spectra showing diastereomeric splitting of 1-phenylethanol as the enantiomeric excess of the 1-phenylethylamine environment is varied from 100% D to 100% L. The inset shows the four possible diastereomeric interactions between the sensor (1-phenylethanol) and chiral solvent (1-phenylethylamine).

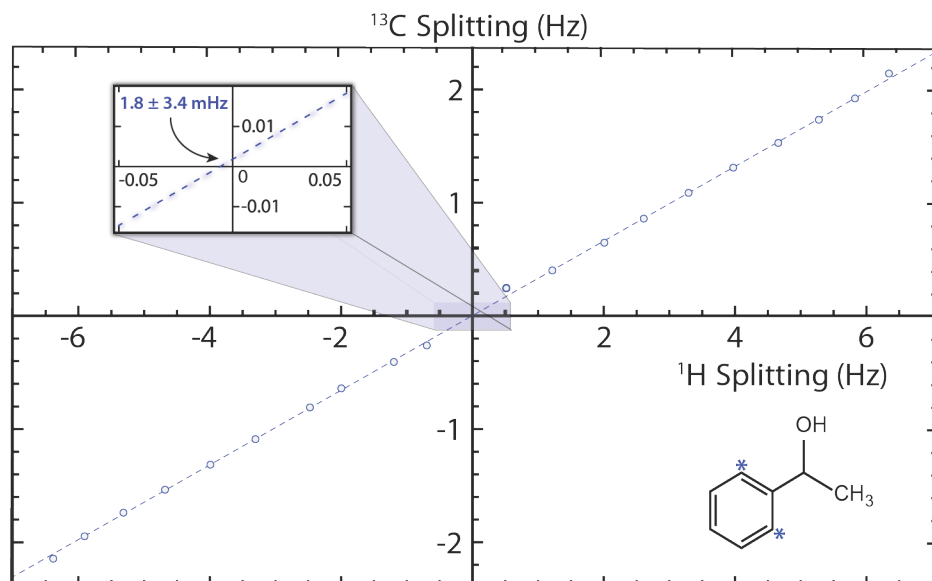


Fig. 2. Experimental data showing the diastereomeric splitting of the ^{13}C peaks vs. the diastereomeric splitting of the ^1H peaks as the chirality of the solvent is titrated. A nonzero intercept on the vertical axis would be an indication of PNC effects.

References

- [1] C. S. Wu, E. Ambler, R. W. Hayward, D. D. Hoppes, and R. P. Hudson. *Phys. Rev.* **105**, 1413 (1957).
- [2] M. A. Bouchiat. *Nuovo Cimento C* **35**, 78 (2012).
- [3] J. Eills, J. W. Blanchard, L. Bougas, M. G. Kozlov, A. Pines, and D. Budker. *Phys. Rev. A* **96**, 042119 (2017).