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## Hydrogen Bonding in Ion-pair Molecules in Vapors over ionic liquids, studied by Raman Spectroscopy and *ab initio* Calculations

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The hydrogen bonding interactions in selected archetypal vapor molecules formed in the gas phase over protic ionic liquids are discussed, based on Raman spectroscopy assisted with *ab initio* molecular orbital DFT-type quantum mechanical calculations (B3LYP with 6-311+G(d,p) basis sets) on assumed gaseous free state models. Some extreme examples are to be discussed: (1) The 1,1,3,3-tetramethylguanidinium chloride “molecule” [TMG-H-Cl] found<sup>1</sup> to exist in gaseous state over its corresponding liquid in evacuated ampouls heated at ~225°C (Fig. 1); (2) the analogous bromide “molecule” [TMG-H-Br]<sup>2</sup> and (3) the 1-methylimidazolium ethanoate, [mim-H-O<sub>2</sub>CCH<sub>3</sub>] found<sup>3</sup> to have a less likely existence in the vapor of the corresponding liquid in ampouls at ~200°C (Fig. 2). Experimental Raman results will be compared to *ab initio* calculated spectra.

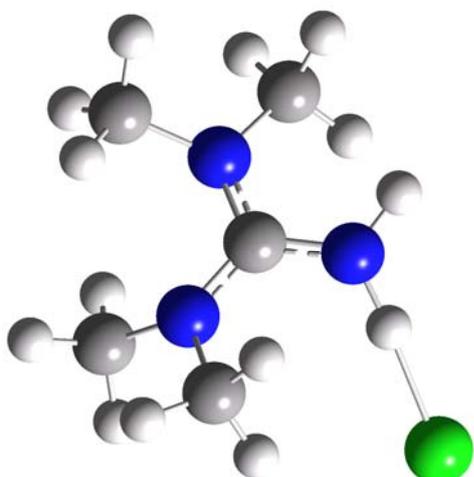
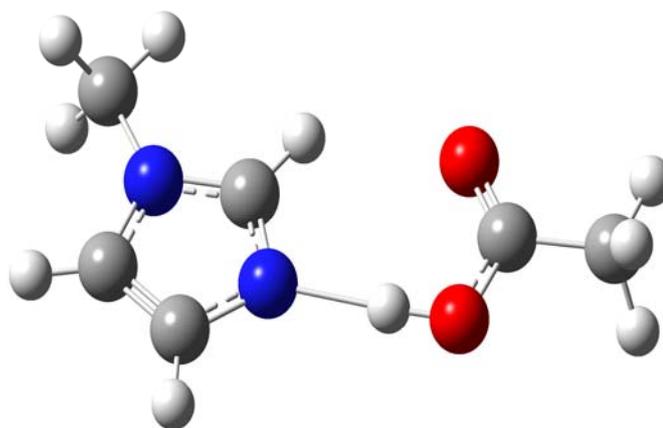


Fig. 1. Likely gaseous ion pair molecule of 1,1,3,3-tetramethylguanidinium chloride. The optimized N-H distance in the N-H $\cdots$ Cl bond was 1.099 Å. The H-Cl distance was 1.832 Å to compare with the ~1.27 Å in HCl gas. The bromide behaved similarly<sup>2</sup>.

Fig. 2. Not so likely 1-methylimidazolium ethanoate gas molecule. The optimized N-H and H-O distances in the N-H $\cdots$ O bond were found as 1.730 and 1.005 Å. The comparable H-O distance in solid ethanoic acid is ~1.011 Å (neutron diffraction).



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- 3 R. W. Berg, J.N.C. Lopes, L.P.N. Rebelo, K.R. Seddon & A.A. Tomaszowska, A Raman Spectroscopic Study of the Vapour Phase of 1-Methylimidazolium Ethanoate, a Protic Ionic Liquid, To be submitted for *J. Phys. Chem. A* (2009).