

# Is “choline and geranate” an ionic liquid or deep eutectic solvent system?

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The definition of CAGE (choline and geranate) presented by Banerjee et al. (1) in PNAS as both an ionic liquid (IL) and deep eutectic solvent (DES) is contradictory, goes against their previous classification of CAGE, and prevents the work from being discussed or understood in context with the appropriate literature. ILs are defined as salts which melt below 100 °C (2), while DESs are eutectic mixtures of two or more distinct components which typically interact via strong hydrogen bonding (3). Membrane transport of ILs and DESs has been shown to be dramatically different (4).

This work is a continuation of the authors' previous work using CAGE, a 1:2 combination of choline bicarbonate and geranic acid, but since they provide no characterization of what CAGE is once the chemicals are combined, one must refer to their earlier papers (5–7) to understand what they have made. To us,

CAGE appears to be what we would call an IL with a complex anion, [choline][geranate<sub>2</sub>(H)] (8).

We believe this is the first paper in which the authors call CAGE an IL [although a 2014 press release called it an IL (9)]. Unfortunately, in the same paper, they also call it a DES. In ref. 7, the authors distinguish between what are true ILs and what are DESs. In the supporting information of ref. 7 the authors clearly list CAGE as a DES and, in both refs. 5 and 6, they call it a DES.

Banerjee et al. (1) have described a great application; however, by using contradictory nomenclature and not citing the literature most closely aligned with their work, the DES-vs.-IL confusion will not help others understand the chemical nature of the system, thus preventing a mechanistic understanding of how this system works. A detailed review of the published literature is warranted to bring context to the CAGE system and help future researchers benefit from this knowledge.

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Conflict of interest statement: The authors are inventors of patents on pharmaceutical ionic liquids [Rogers RD, et al. (2012) Multi-functional ionic liquid compositions for overcoming polymorphism and imparting improved properties for active pharmaceutical, biological, nutritional, and energetic ingredients. US Patent 8,232,265; and Rogers RD, et al. (2016) Dual functioning ionic liquids and salts thereof. US Patent 9,278,134.] and are shareholders of 525 Solutions, Inc.

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