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Where was the potassium, [K^+]?

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All living cells have high intracellular potassium concentrations, [K^+]. How and when did this high [K^+] appear? There are 2 choices:

1. The prebiotic environment was high in [K^+] = "Early K^+"
2. The prebiotic environment was not high in [K^+], but protocells created a high intracellular [K^+], from an environment that was not high in [K^+] = "Late K^+".

There are problems with both options.

"Late K^+" has the problem of how such an elemental aspect of life could have arisen after other processes in the origins of life had begun. The high intracellular [K^+] is now maintained by an energetically expensive pump, the Na^+/K^+- ATPase.

"Early K^+" has the problem: where was the [K^+]? It was not in seawater, which has 40x more Na^+ than K^+. Two possibilities have been published: in geothermal fields [1], and between the sheets of mica or biotite in micaceous clay [2, 3]. Neither possibility is ideal.

The geothermal fields are described as 'vapor-dominated,' and there is not convincing data about the excesses of K^+ over Na^+ in geothermal fields [1]. Mica has several advantages [2, 3]. Some of these are the following: Mica was present in the Hadean, and mica's anionic mineral sheets are held together by a hexagonal grid of K^+, with a periodicity of 0.5 nm, which is also the spacing of anionic phosphate groups in extended single-stranded nucleic acids, DNA and RNA. Most micaceous clay, however, appeared later on Earth.

This question, "where was the K^+?" is an elephant in the room of research on the origins of life.

[1] Mulkidjanian, A. Y., et al. (2012), *Proc Natl Acad Sci U S A* 109, E821-830.

[2] Hansma, H. G. (2010), *Journal of Theoretical Biology* 266, 175-188.

[3] Hansma, H. G. (2020), *Preprints* 2020090409.