Origin of Life from the View Point of Chemical Catalysis

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A kinetic analysis of the steady state replication of molecules X_i due to consumption a "food" R via simple autocatalytic processes like

$$R + X_i \underset{k_{-i}}{\overset{k_i}{\rightleftharpoons}} 2X_i\,, \qquad X_i \xrightarrow{k_{ti}} P,$$

and its more complicated analogs demonstrates inevitability of arising an irreversible and thus progressive evolution of autocatalyst molecules X_i, if only the autocatalysts can undergo a chemical mutation and the concentration of "food" R can fall below a critical value

$$R_{cri} = k_{ti} / k_t\,.$$

The natural selection of simple autocatalysts mimics a protolife and occurs in ***only one direction*** toward minimizing the value of R_{cri} which is improved through the mutation. The driving force of this selection is the *long-term* existence of a deficiency in "food" R.

No doubt, this ability of simple autocatalytic systems to an irreversible progressive evolution is a total analogy of the existence of a primitive biological memory. This evidences in the possibility of starting a progressive prebiotic evolution even in the absence of special evolution information carriers like RNA or DNA molecules.

One of the most plausible candidates for the first protolife autocatalytic reaction is the well known "formosa" reaction of autocatalytic polymerization of formaldehyde into a variety of C_3-C_6 monosaccharides in water solution catalyzed by the dissolved omnipresent calcium cations. Note, that formaldehyde was also a typical constituent of the Protoearth atmosphere. Mutation of saccharides is very easy and can be exemplified by any chemical modification of saccharide molecules, e.g., by nitrogen- or phosphate-containing derivatives, with the formation and progressive selection of initial biological building blocks.

One may expect that the natural selection in abiogenous formosa systems could serve as a trigger of evolution mechanism. Also, formosa systems themselves may be a real precursor of appearance of the first and most primitive, but operating RNA molecules that resulted later in the first biological systems. Thus, the RNA or DNA molecules could be not a reason but a consequence of the quite rapid prebiotic evolution, their structure being predetermined by the primary saccharide selection.

References

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The role of radon and colloids in distorting the U-Pb age dates of geologically young minerals deposited in open cavities

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Due to the improving accuracy and decreasing detection limits of the isotope analyses, the U-Pb method is becoming increasingly popular for dating geologically young (Miocene-Pliocene) materials. Typically, large concentrations of U along with small concentrations of Pb are considered necessary and sufficient prerequisite making a material suitable for the dating. Uraniferous opals associated with U-rich rhyolitic volcanic rocks commonly meet the criterion.

Complications may arise when minerals are deposited in open cavities (e.g., large-aperture fractures or lithophysae) because the decay series employed for dating, ^{238}U-^{206}Pb and ^{235}U-^{207}Pb, contain intermediate isotopes of Rn. Due to the diffusion of the latter, radiogenic Pb isotopes originated from the decay of U in the bedrock preferentially accumulate in the water- or gas (air)-filled cavities. Examples of modeled concentration profiles are shown in Figure.

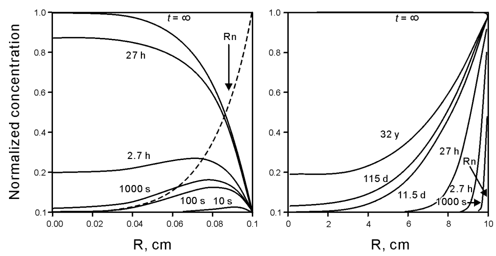

Figure. Normalized concentration profiles ([Rn]=1 at cavity wall) for $^{207}Pb_{Rn}$ (solid lines) and ^{219}Rn (dashed line) in spherical cavities with R = 0.1 and 10 cm.

Minerals depositing in cavities should uptake these Rn-derived (Pb_{Rn}) isotopes according to the water-mineral distribution coefficients. The uptake would be particularly efficient if mineral growth involves colloidal solutions, as it is commonly the case with uraniferous opals. Micelles of silica absorb Pb_{Rn}, which upon coagulation and sedimentation of the colloid becomes incorporated in opal.

Developed mathematical model of the process considers diffusion migration of Rn and Pb_{Rn} isotopes, water flow, as well as coagulation of micelles and sedimentation of particles.

In rhyolitic bedrock ($[U_{rock}] \cong 5$ ppm), opal formed through precipitation of micelles with characteristic radii r = 10 nm may acquire on the order of 100 ppb of $^{206}Pb_{Rn}$ and 10 ppb of $^{207}Pb_{Rn}$. For a typical uraniferous opal with $[U_{opal}]$ = 200 ppm this would translate into apparent U/Pb age dates of between 4 to 5 Ma.