

# Chemical evolution as a concrete scheme for naturalizing the relative-state of quantum mechanics

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## ABSTRACT

The evolutionary onset of a reaction cycle such as an autocatalytic cycle requires a reliable framework for protecting the harbinger cycle, once it appears by any chance, against the hostile environments in the neighborhood. One natural candidate for protecting the fragile nascent cycle could be available from the operation of internal measurement envisioned in the relative-state formulation of quantum mechanics. Once every chemical reactant is taken to be relative to every other reactant in the act of measuring each other internally, the relative-state formulation provides the condition for favoring and protecting those events such that the reactions mediating between the reactants and the products may eventually form a reaction cycle.

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## 1. Introduction

Despite that the significance of the onset of an autocatalytic reaction cycle in chemical evolution cannot be overemphasized (Kauffman, 1986), its spontaneous appearance alone does not directly guarantee the subsequent evolutionary fixation (Matsuno, 2011). The evolutionary likelihood of fixing a reaction cycle requires more than a haphazard appearance of a reaction cycle. It also requires some protective means, which may be in the form of either a built-in software already installed in the reaction cycle or an additional hardware to be implemented externally, or neither of the two alternatives. A naked reaction cycle with no protective means would have been quite vulnerable to the hostile environments in the prebiotic setting. One likely strategy toward figuring out the nature of the material agency providing such protective means may be found in the appraisal of the identification–interaction proceeding in the reacting chemicals since the reaction systems are taken to be sentient to their outside, whether it may be benign or hostile to them, from the outset.

The identification–interaction occurring in the reacting chemicals is a form of measurement proceeding internally (Matsuno, 1989), and internal measurement is necessarily relative in mediating between any pair of reacting chemicals. Every reactant comes to identify the interaction partner internally in a manner of being relative to each other. In this regard, Everett's relative-state formulation

of quantum mechanics is suggestive in formally addressing the act of internal measurement (Everett, 1957). In essence, the occurrence of a quantum state relative to any other state is taken to be a measurement proceeding internally in the relative-state formulation. The measurement of the state of an object is relative to the state of the measuring instrument or a measuring body of whatever sort, otherwise the identification of the state of the object may be jeopardized. Thus, the relative-state formulation may provide us with a new opportunity for coping with the identification–interaction without asking the help from the external agency of measurement, such as the physicist preparing the measurement apparatus externally.

## 2. Internal Measurement Underlying A Reaction Cycle

Let us suppose a sequence of chemical reactions  $R_1 \rightarrow R_2 \rightarrow \dots \rightarrow R_n$ , where  $R_i$  ( $i=1, 2, \dots$ ) denotes each intervening reactant. The presence of reactant  $R_1$  is identified by the whole reaction system except for the targeted reactant  $R_1$ , which is denoted as  $O_1$ , as expressed in the conventional quantum-mechanical form of the state representation:

$$|R_1\rangle|O_1R_1\rangle$$

Here,  $|R_1\rangle$  denotes the quantum state of reactant  $R_1$  and  $|O_1R_1\rangle$  denotes the quantum state of the material support  $O_1$  upholding and observing reactant  $R_1$  internally as such (Matsuno, 2007). Each quantum state throughout will be taken as a vector of unit length in the corresponding Hilbert space as a matter of convenience. A significance of the present expression is found in the aspect that the

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identification of  $R_1$  is made possible only in relation to the material support  $O_1$  in charge of identifying  $R_1$  internally as such. The dynamic factor mediating between the reactant  $R_1$  and the material support  $O_1$  is internal measurement proceeding between the two. It is not directly accessible to the measurement with use of the apparatus designed and prepared by the physicist for the sake of external measurement.

In addition, the state representation  $|R_1\rangle |O_1 R_1\rangle$  in the relative-state formulation would still remain incomplete unless it is further supplemented by the scheme of specifying another material carrier that can observe and identify the material support  $O_1$  internally. Exactly at this point can enter the reaction  $R_1 \rightarrow R_2$  as letting the emerging reactant  $R_2$  assume the role of observing the material support  $O_1$  internally as such even temporarily. Needless to say, the reactant  $R_2$  again requires another material support  $O_2$  for its own internal identification by way of reshuffling the incumbent material support  $O_1$  and transforming it into  $O_2$ . This sequence may be reiterated indefinitely.

Thus, external identification of the reaction  $R_1 \rightarrow R_2$  can be made likely by applying an externally controlled projection to the consequence of the dynamics of internal measurement if one remains indifferent to what would be going on internally right in the reshuffling-process of the material support from  $O_1$  to  $O_2$ . The quantum decoherence ascribed to the reshuffling-process to be done for the sake of the conservation of probability applied to the splitting or branching vectors in the relevant Hilbert spaces is indispensable to internal measurement because of the absence of the means for the global coordination in a concurrent manner on the spot. Despite that, such decoherence can be made invisible to external measurement taking the conservation of probability to the global extent for granted from the outset. The rationale of the introduction of external measurement is upon the standard convention of distinguishing the transformed product  $R_2$  from the reactant  $R_1$  to be transformed, that may be accessible to the physicist or chemist observing the reaction from the outside without paying attention to what is going on during the reshuffling-process internally. In fact, the quantum Zeno effect reveals that transformation of a quantum state is identifiable in a coherent manner through the repeated intervention of external measurement (McFadden, 2002).

The reaction  $R_1 \rightarrow R_2$  can thus be approached as an instance of the external projection applied to the material support  $O_1$  for the sake of the transformation of  $R_1$  into  $R_2$ . This reaction is further assisted by the preparation and participation of another material support  $O_2$  for upholding and observing  $R_2$  internally. The present scheme of projection is symbolically summarized as

$$M_2|R_1\rangle|O_1 R_1\rangle = \alpha_2|R_2\rangle|O_2 R_2\rangle \quad \text{with} \quad |\alpha_2| < 1$$

Here,  $M_2$  is an externally accessible operator for projecting  $R_1$  onto  $R_2$ , and  $O_2$  is the whole reaction system, except for the targeted  $R_2$ , functioning as the material support for upholding and observing  $R_2$  internally. The complex number  $\alpha_2$  above is equated to the complex amplitude of the consequential state vector that depends upon the very internal nature of the involved measurement-interaction causing its branching. The absolute value of the amplitude  $\alpha_2$  will remain less than unity unless the prepared quantum state of reactant  $R_2$  happens to be one of the eigenstates of reactant  $R_2$ .

The advantage of referring to the complex amplitude  $\alpha_2$  is in its implicit reference to the dynamics of internal measurement that is not directly accessible to external measurement. The absolute value of the complex amplitude  $\alpha_2$  is in fact associated to the probability amplitude conceived of within the relative-state formulation under the constraint that the conservation of probability to unity is applied to the total sum of all of the branching states (Everett, 1957; Wheeler, 1957). What should be focused upon here is that the probabilistic characteristic latent in each relative-state remains intact

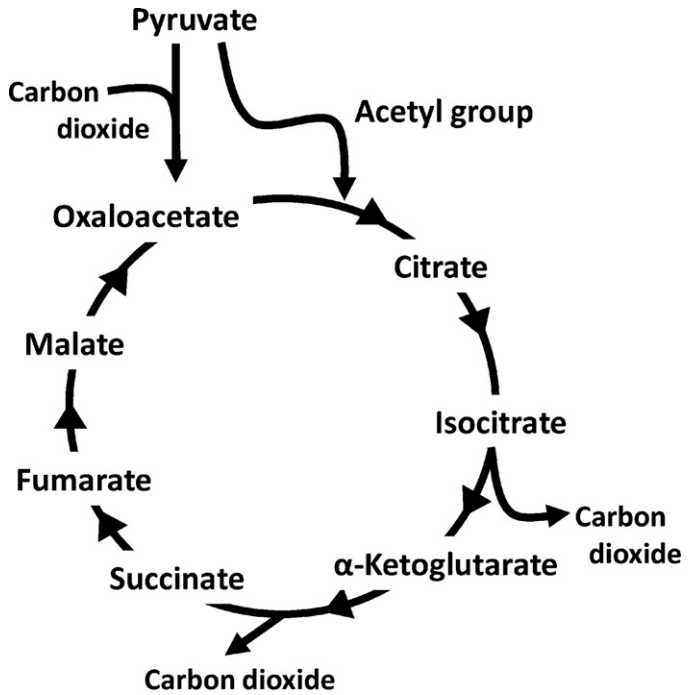


Fig. 1. A schematic diagram of the citric acid cycle, that is oxidative.

and survives even after each act of internal measurement. This is the aspect that is distinctive compared to the standard Copenhagen interpretation, the latter of which allows for none of probabilistic nature left behind once external measurement attempted by the physicist has been completed.

Thus, as repeating the similar projection of external origin in reference to the consequence of internal measurement, the reaction system can yield its multiplicative effect as expressed in the form:

$$M_n M_{n-1} \cdots M_2 |R_1\rangle |O_1 R_1\rangle = \alpha_2 \alpha_3 \cdots \alpha_n |R_n\rangle |O_n R_n\rangle$$

with  $|\alpha_i| < 1$  ( $i = 2, 3, \dots, n$ ).

Furthermore, if the material support  $O_n$ , after being subject to another projection of measurement-interaction  $M_1$ , happens to prepare the start-up support  $O_1$  that can also uphold and observe the start-up reactant  $R_1$  internally, the resultant contribution will amount to a reaction cycle

$$M|R_1\rangle|O_1 R_1\rangle = \alpha|R_1\rangle|O_1 R_1\rangle$$

with  $M = M_1 M_n M_{n-1} \cdots M_2$ ;  $\alpha = \alpha_2 \cdots \alpha_n \alpha_1$ ;  $|\alpha| < 1$ .

What is unique to the occurrence of the reaction cycle is a total naturalization of the relative-states in the sense that every state is relative to every other along the closed reaction pathway without introducing any privileged or preferred state of external origin.

Then, we can estimate some of the contributions of the measurement dynamics of external origin. If the physicist decides to identify the characteristics of the reaction system at every time interval of  $\tau$ , that is arbitrarily chosen, and lets the system develop upon the dynamics of internal measurement on its own during over each interim period, the contribution of the multiplicative projection of measurement-interaction over the time period  $t(>\tau)$  would reduce to

$$M^\mu |R_1\rangle |O_1 R_1\rangle = \alpha^\mu |R_1\rangle |O_1 R_1\rangle \quad \text{with} \quad \mu = t/\tau.$$

For the initial state  $|R_1\rangle |O_1 R_1\rangle$  to which the projection of measurement-interaction applies is updated at every time interval  $\tau$  externally. A key assumption employed at this point is that the dynamics of internal measurement may not be disturbed by

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