Polymerization and decomposition reactions upon heating of an amino acid (threonine) simulating the chemical evolution of life

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The emergence of the first life on the earth is the result of a long period of chemical evolution. Although a large number of simulation experiments for the polymerization processes in the chemical evolution has been conducted, little is known for the transformation mechanisms and kinetics of organic molecules and suitable environment such as temperature and redox conditions for the chemical evolution. Most previous studies have been focused on the question whether polymers were formed or not. However it is important to evaluate the time scales of the polymerization processes and stabilities of synthesized polymers.

A series of heating experiments of an amino acid solution had, therefore, been conducted by using threonine as a representative organic molecule, in order to evaluate the time scales of polymerization processes and stabilities of synthesized polymers.

Threonine concentrations decreased with time at higher temperatures. Glycine was formed in all the solutions where threonine concentration decreased, suggesting the transformation of threonine into glycine under these conditions. However, the glycine yields were much less than those were expected by the total conversion of threonine into glycine. Therefore, side reactions other than threonine to glycine conversion are considered to occur in the present study. In fact, trace amounts of a peptide (glycyleglycine) was formed and its concentration increased with time at 131 and 141C. Brown stuff was formed in solutions and film-like products were observed on the heated solutions. The film formation was faster at higher temperatures. These are supposed to be polyester films.

These results have been treated kinetically by using a supposed reaction schema (2glycine to glycylglycine reaction is the 2nd order reaction and the rest of reactions are the 1st order). The obtained apparent rate constants k (=k1+k2) showed a good agreement with the literature data (Vallentyne, 1964). The k1 and k2 values showed different trends in an Arrhenius diagram with a crossing temperature point (near 140C). Above crossing point, the decomposition reaction [Thr] to [Gly] has larger rate constants (k1) than the polymerization reaction (k2). On the other hand, at temperatures under the crossing point, the polymerization reaction [Thr] to [Brown stuff] has larger rate constants (k2). These mean that a dominant reaction of the system inverses at the crossing temperature point. Therefore excessive high temperatures are considered to be unfavorable environment for the polymerization reaction in the chemical evolution, because of the faster rates of decomposition reaction.