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Stability of Glycine in Saline Solutions Exposed to Ionizing Radiation

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ABSTRACT

The stability of biologically important molecules, such as amino acids, being subjected to high-radiation fields is relevant for chemical evolution studies. Bodies of water were very important in the primitive Earth. In these bodies, the presence of dissolved salts, together with organic molecules, could influence the behavior of the systems in prebiotic environments.

The objective of this work is to examine the influence of sodium chloride on the stability of the amino acid glycine when subjected to high radiation doses. The analysis of the irradiated samples was followed by HPLC coupled with a UV-VIS detector. The results show that glycine in aqueous solutions (without oxygen) decomposed around 90% at a dose of 91 kGy. In the presence of salts, up to 80% of the amino acid was recovered at the same dose. Laboratory simulations demonstrate a protective role for sodium chloride (specifically the chloride ion) to glycine against an external source of ionizing radiation.

1. Introduction

The understanding of the processes occurring on our planet leads us to use the principle of actualism. In a more general way, the assumption can be extended that the same physical and chemical laws that govern today also governed primitive Earth.

Chemical evolution encompasses the formation of biologically relevant organic compounds as well as their subsequent increase in complexity through physical and chemical events [1-2]. In stages of the early Earth, the hydrosphere, lithosphere, and atmosphere, as well as their interactions, played core roles in chemical evolution.

For a chemical change to occur, the combination of the matter and energy capable of stimulating the process is essential. Ionizing energy was an important source of energy in the primitive Earth [3]. In aqueous environments, water absorbs this energy. High radiation induces the formation of free radicals on water. Free radicals generally have a high diffusion capacity [4] and can quickly attack organic molecules in the environment.

On Earth, liquid water began to accumulate at around 4.4 Ga [5] and salts originated from the gases in volcanic activity and the weathering of rocks. In this context, the Earth's surface had bodies of water with a wide range of conditions and salinities. The role of salts is important for chemical evolution studies. Its presence modifies various parameters in the environment such as gas solubility [6], electrostatic forces and solvent-induced forces [7], and water activity.

Amino acids are basic organic molecules for biological systems. Synthesized under a variety of prebiotic scenarios, glycine has one of the highest yields among amino acids [8].

Our aim is to study the effect of salts (chloride) in aqueous glycine solution exposed to high-radiation fields to simulate the chemical reactions that occurred in a primordial saline system.

2. Experimental procedure

2.1 Samples

All of the chemicals used were of the highest purity available. The glycine and other chemicals were obtained from Sigma-Aldrich Co., USA. We used triple-distilled and deionized water to prepare the solutions. The glassware was treated according to standard techniques in radiation chemistry.

The concentration of the aqueous solutions of glycine and sodium chloride were and respectively. The solutions were at a natural pH 6. The oxygen was removed of solutions by bubbling argon for 10 minutes.

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2.2 Irradiation

Irradiations were carried out with a ^{60}Cobalt gamma source (Gammabeam 651-PT) at Nuclear Sciences Institute, UNAM. The absorbed doses were from 0 to 91kGy. The samples were irradiated at selected irradiation times in a closed oxygen-free glass tube at room temperature.

2.3 Analysis of Samples

The samples were analyzed with high-performance liquid chromatography (HPLC) (Varian 9010) using a C18 column (SUPELCO, 25 cm in length and 4.6 mm internal diameter). For the HPLC analysis, Varian liquid chromatography was coupled with a UV-VIS detector.

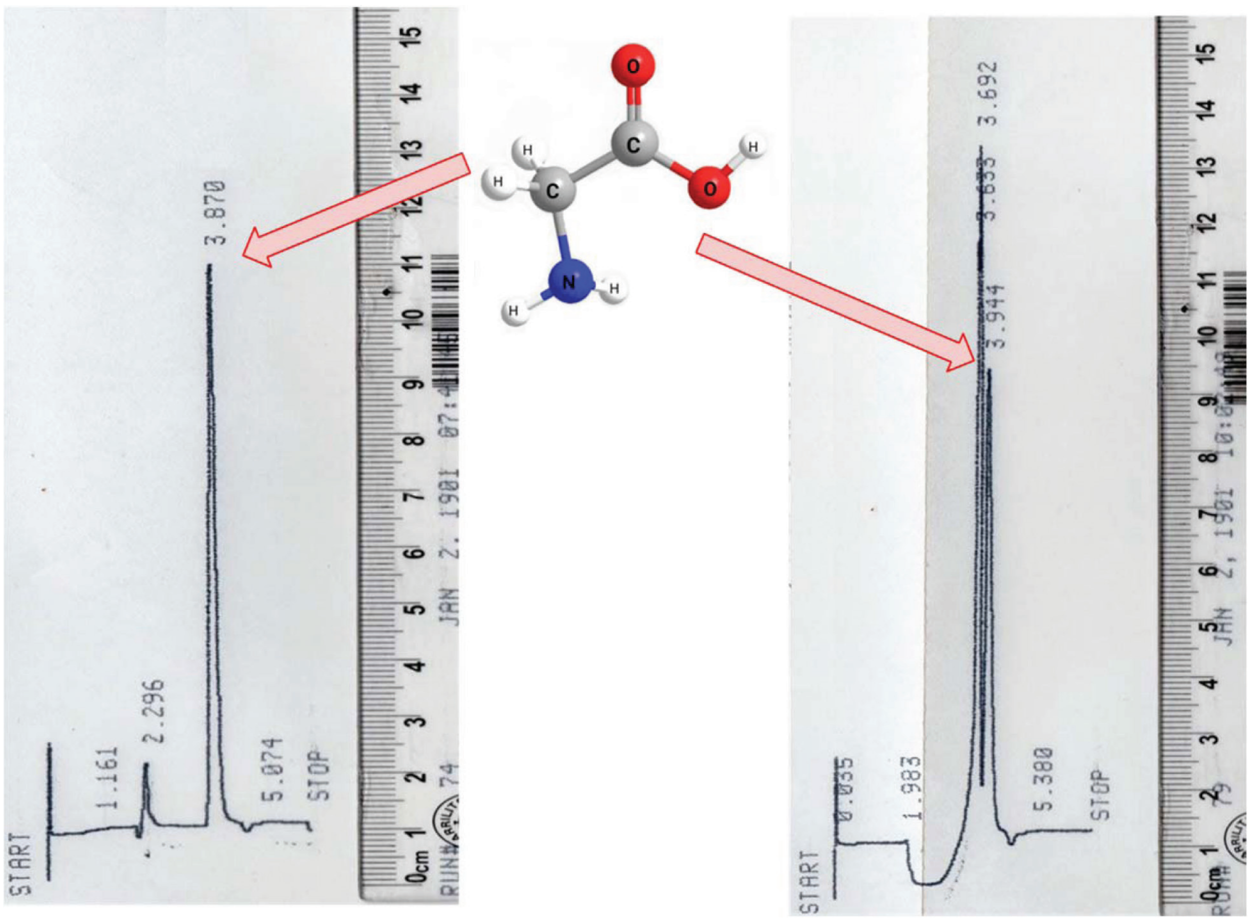

Figure 1: Standards of glycine. The chromatograms show thesignal of standards of glycine in aqueoussolutions (left) and in saline solutions (right).

UV analysis was performed at 210 nm. The identification of glycine (Figure 1) and remnants after irradiations, was based in the irretention times in HPLC and co-injections with internal standard. The measurements were carried at room temperature.

3. Results and discussion

It is important to understand the effects of prebiotic environments in organic molecules, to know about not only their formation but also their stability in such environments. Glycine decomposition during irradiation experiments was quantified by HPLC coupled with a UV detector at 210 nm. To evaluate the dose effect, the heights of the peaks were used to calculate the recovery percentage (Figure 2).

Glycine's (aqueous solution) decomposition was dose dependent (Figure 3). The experiments in the presence of salts under the same dose as that of the aqueous solutions showed higher analyte recovery.

Glycine irradiation in the presence of sodium chloride partially demonstrated that the presence of the salt decreased the damage to the glycine as a result of the action of ionizing radiation. The mechanism for this protection is probably the charge-transfer phenomenon between each hydroxyl radical

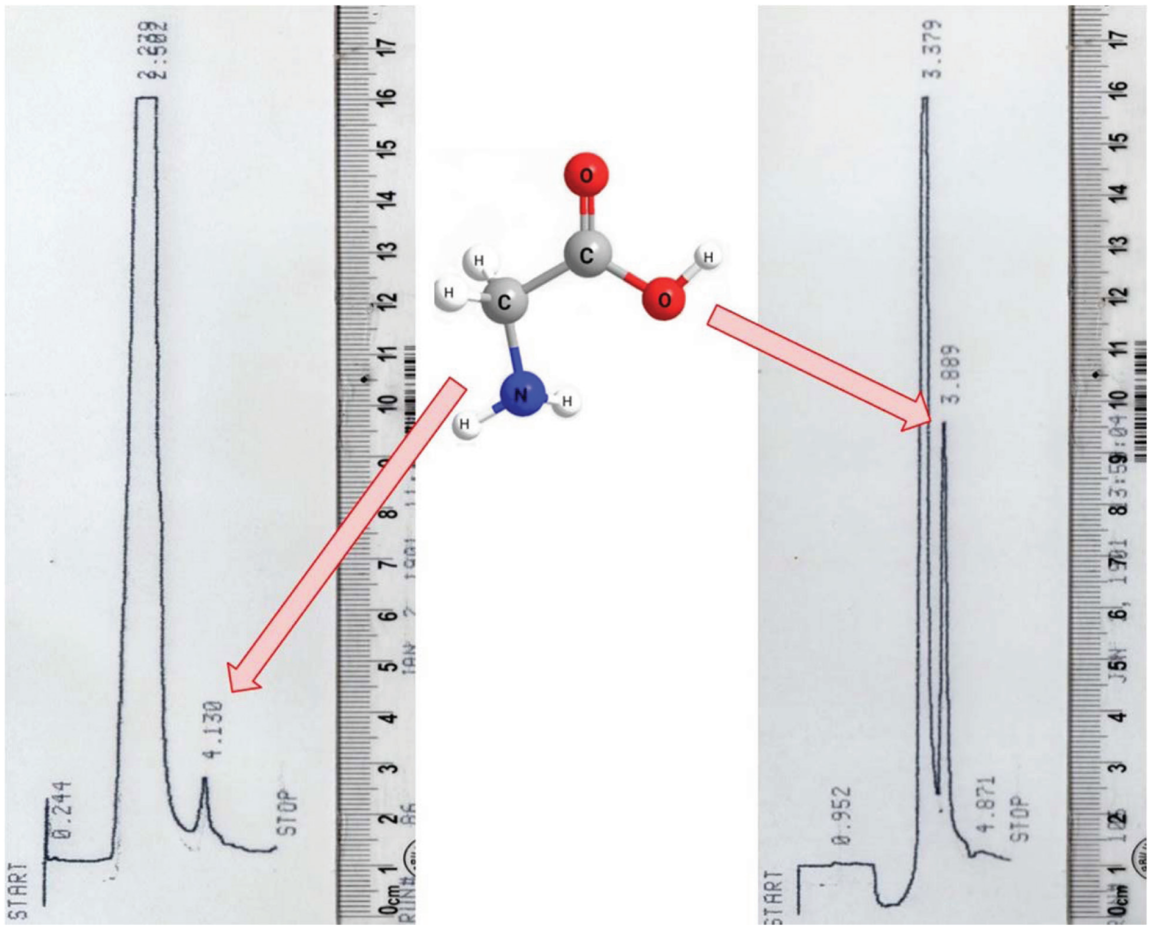

Figure 2: Response of glycine solutions irradiated at 91kGy. The chromatograms shows response of aqueous glycine solutions (left) and saline glycine solutions (right) after 91 kGy irradiation dose.

and chlorine ion. In aqueous solutions, hydroxyl radicals quickly attack glycine molecules, but in saline solution, the high concentration of chlorine ions competes for the radicals in the propagation stages.

4. Remarks

A different level of stability was observed for glycine in this prebiotic simulation. The aqueous glycine solutions showed a direct decomposition with radiation dose. Saline glycine solutions allow recover more than 80% of the initial concentration to be recovered. These partial results suggest that chlorine ions may provide protection to glycine against ionizing radiation.

Saline environments could be reservoirs of organic molecules, ensuring their permanence in the environment for future reactions. In chemical evolution studies, this kind of simulation gives clues to better comprehend the chemical steps that led to the appearance of life on Earth.

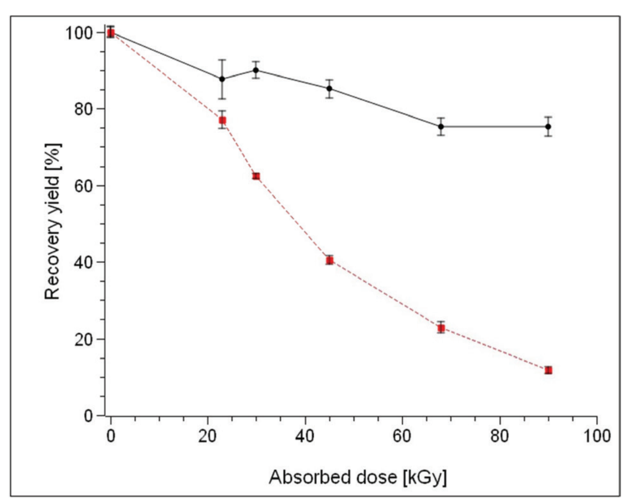

Figure 3: Behavior of glycine. The dashed line (red) represents the percentage of recovery yield of glycine after irradiations in aqueous solutions, and the solid line (black) is glycine's percentage of recovery yield in the saline solutions.

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