Synthesis of Bio-important Organics in Post-impact Plumes

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It has been established that 20 key essential amino acids, specifically L-form amino acids are used by life for protein synthesis which is important in many biological reactions such as the replication of RNA as well as DNA. Previous works have shown some of the earliest amino acids could have been formed through meteoritic impacts during the Late Heavy Bombardment (LHB) ca. 4 billion years ago. During the LHB, the planets of the inner solar system were impacted by a higher frequency of meteors than present era.

Many meteors contain materials conducive to in situ amino acid formation such as carbon and metallic iron. Carbon is necessary for amino acids, and metallic iron has the ability to catalyze organic synthesis. Water in the early oceans would have provided both an oxygen and hydrogen source. Nitrogen would have been present in the early atmosphere, which was likely N_2 and CO_2 rich. Thus, Nitrogen, Carbon, Oxygen and Hydrogen would all have been present. These four elements are the essential ingredients of building amino acids.

Previous experiments have tested the impact hypothesis. Work outlined in a previous study used shock recovery experiments simulating impact induced reactions with meteorite analogs with solid C and bicarbonate as the carbon source (Furukawa et al. 2009; Furukawa et al. 2015). However, some conditions in laboratory shock-recovery experiments are different from natural impacts, in particular the duration of heating. Further, previous shock experiments used ammonia as a nitrogen source but the amount of ammonia in the prebiotic ocean was limited. A following work investigated the compositions of evolving gases in impacts by a gas-flow experiment with longer heating duration than shock-recovery experiments without ammonia and showed the formation of CO, CO_2, NH_3, and HCN (Furukawa et al. 2014). However, it remains unclear which of life’s building blocks form by longer interactions of evolved gases in post-impact plumes.

We conducted a gas circulation experiment in a glass-made circulator line made for this experiment. The line was evacuated and then filled with N_2. A meteorite analogue was placed in the reaction tube which is a part of the circulator line and heated at 1000°C. The circulator line is equipped with a water flask which provides water vapor to the reaction tube. The thermochemical reaction products are introduced in a condenser tube in which water vapor condenses and some soluble gases dissolve in the condensed water but most of the product and unreacted gases were re-circulated in the circulator line and reintroduced into the reaction tube. Meteorite analogue was composed of iron, nickel, amorphous ^{13}C. It was separated from the surrounding gold tube by SiO_2 silica wool. The silica wool and gold are not part of the reactions. In other conditions, $NaHCO_3$ was added to the meteorite analogue to generate CO_2 in the gas circulator. Further, in some experiments, ammonia water was used in place of water in the water flask. Duration of the experiment is 6 hours.

The products are collected, condensed, and analyzed for amino acids and amines with liquid chromatography and mass spectrometry. In all experiments other than control experiments, glycine, methylamine and ethylamine were demonstrated. The yields of glycine depended on the concentration of ammonia provided to the reaction tube. Glycine is an essential amino acid for life, and this experiment demonstrates that early impacts could have been a source of glycine and amines on the early Earth, and

could have been formed even in a non-reduced nitrogen environment.

Keywords: organics, early Earth, amino acid , prebiotic, meteorite impact