SHOCK SYNTHESIS OF PREBIOTIC MOLECULES I: PRELIMINARY RESULTS. V. Spathis[1], M. C. Price[1], J. D. Tandy[2], J. S. New[3] and P. J. Wozniakiewicz[1], [1]School of Physical Sciences, University of Kent, Canterbury, Kent, CT2 7NH, UK (E-mail v.spathis@kent.ac.uk), [2]School of Human Sciences, London Metropolitan University, London, N7 8DB, UK, [3]Space Sciences Laboratory, University of California, Berkeley, 7 Gauss Way, CA 94720, USA.

Introduction: Impact phenomena are commonly associated with destruction, but it is through these violent events that environments and conditions necessary for life may have been created [1, 2]. Theoretical simulations investigating both the development of the reactants required for synthesis, along with the formation of prebiotic molecules in the primordial Earth, have shown that impacts from cometary ices could have yielded a wide variety of prebiotic organic material [3 - 14]. Furthermore, these processes have been shown to sometimes be independent of external factors, such as the presence of a catalyst, UV irradiation, or pre-existing conditions on a planet [15], further reinforcing the significance of impacts in shock synthesis of materials.

In order to determine the validity of these theoretical simulations and further understand the processes experienced during impact, laboratory experiments were developed investigating amine, peptide and amino acid formation [16 - 27], as well as their survivability from subsequent impacts [28 - 30]. Here, the effects of a shock produced during a >7.5 kms^{-1} impact onto an ice target mixed with glycine were examined, to investigate whether the glycine would be modified and another amino acid synthesised as a result of this reaction.

Materials & Methodology: The University of Kent's two-stage LGG [31] was used to horizontally accelerate the projectile prior to impact, and the samples were analysed using an HP-Agilent 6980 / 5973 GC-MS fitted with a ZB-5 MS column.

Experimental Methodology: A 3.1 mm diameter solid nylon sabot projectile was fired onto an ice target mixture at 7.604 kms^{-1}. The target mixture consisted of 50 g >99.8 % glycine dissolved in 1 L HPLC-grade water and placed in a sterilized stainless-steel container. The target mixture was frozen to -120 °C, with the temperature increasing to approximately -50 °C during the evacuation process of the LGG target chamber (to 50 mbar), prior to firing.

Analytical Methodology: Post-firing the target sample was covered and placed in a vented furnace at 75 °C to evaporate the water, leaving behind the crystals used for analysis. Crystals extracted from the samples were then placed in a vacuum oven at 75 °C overnight to dry completely prior to derivatization for GC-MS analysis using Sigma-Aldrich & Katherine K. Stenerson's methodology [32]. Once dried, 0.1 M HCl was added and the sample was placed in a vented oven at 150 °C until the HCl had evaporated. The sample was then placed in a vacuum oven at 85 °C overnight to dry completely once again. MTBSTFA (Figure 1) and acetonitrile were then added to the sample before covering and placing back in a vented oven at 100 °C for 4 hours. The sample was filtered through a 0.2 µm PTFE filter prior to GC-MS analysis.

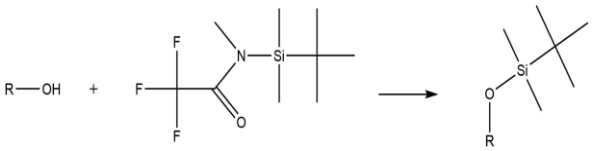

Figure 1: The structure and reaction between MTBSTFA and the polar OH functional group. MTBSTFA replaces active hydrogens in the amino acid OH, NH_2 and SH polar groups with a nonpolar moiety to allow for GC-MS analyses.

Results: The results from this experiment indicate that although glycine was still detected, isoleucine was successfully synthesised using the shock experienced during the impact process (Figure 2).

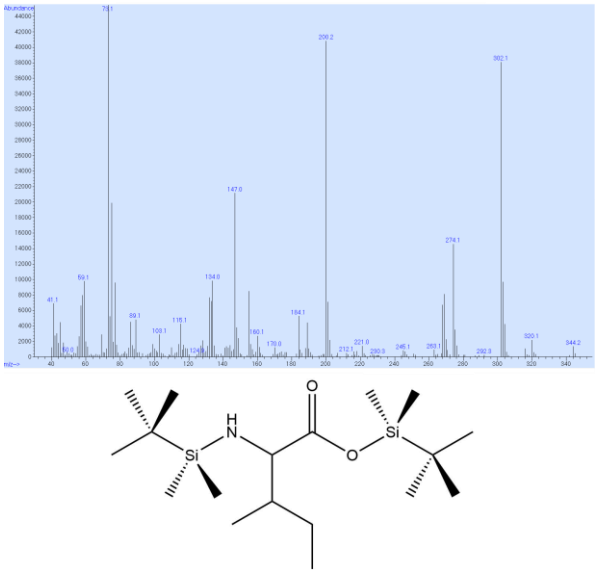

Figure 2: Mass spectrum (and structure) of the isoleucine 2TBDMS derivative detected in the target sample.

Discussion: The results from this experiment demonstrate that amino acids can be modified from the shock experienced during impact to synthesise longer-

chain amino acids. Looking at the structure of glycine (Figure 3) and comparing it to that of L-isoleucine (Figure 4) the compositional difference can be seen.

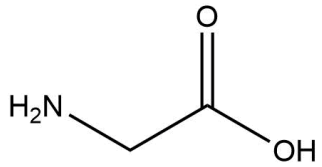

Figure 3: Structure of glycine ($C_2H_5NO_2$).

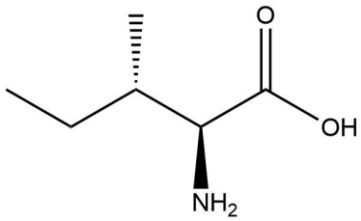

Figure 4: Structure of L-isoleucine ($C_6H_{13}NO_2$).

This suggests that bodies carrying (or consisting of) organic compounds, such as comet *Wild 2* on which glycine was detected [33], could be undergoing shock synthesis when impacted during their travels through our solar system. Consequently, shock synthesis may be more widespread in the universe than anticipated and, depending on what the targets and impactors consist of, this could lead to even more complex structures, including sulphur-possessing and aromatic compounds [34].

Conclusions & Future Work: The preliminary experiment carried out demonstrates that amino acids can be modified through the shock experienced during impact. This can greatly assist in the study of shock synthesis as it suggests that longer, more complex organic structures can be synthesised through hypervelocity impacts. Therefore, although it is possible that shock synthesis may be prevalent throughout our solar system, the parameters under which synthesis occurs (i.e., temperature and pressure) may be restricted. Therefore, peak temperatures and pressures achieved during impact, that lead to successful organic shock synthesis, need to be investigated. Experimental work on both of these is reported in [35] and [36], both of which are in these proceedings.

These preliminary results demonstrate that both the premise of the experiment, as well as the analytical methodology used, have both been successful. This experiment is being repeated to confirm the result prior to publication, but the experimental protocol will also be expanded upon, by doping the ice target mixture with sulphur, in the hopes to synthesise cysteine and simulate the surface of icy bodies like Europa. If this is achieved, even more complex organic structures could potentially arise in future shock synthesis experiments through the formation of disulphide bonds.

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