I. Introduction

Measurements of Venus surface chemistry suggest a basallic composition with a predominantly CO₂ atmosphere. In order to understand the reactivity of certain possible mineral species on the surface, previous simulation chambers conduct experiments at 1 atm with a simplified CO₂ atmosphere. Following this procedure, pyrite (FeS₂) samples are used to estimate the reactivity of sulfide minerals under a Venusian atmosphere and climate. Sulfuric gas species have been identified and quantified in the Venusian atmosphere, and sulfuric gas and mineral species are known to be created through volcanism, which is suggested to still occur on the surface of Venus. This experimentation is necessary to constrain reactions that could occur between the surface and atmosphere of Venus to understand terrestrial geology in a thick and hot greenhouse atmosphere. Quantifying this reaction can lead to approximations necessary for further experimentation in more complex environments such as those in the GEAR chamber at Glenn Research Center that can simulate pressures along with temperature and a more inclusive and representative Venusian atmosphere.

II. Samples

Figure 1 shows samples of pyrite were salvaged from the Cleveland Museum of Natural History. The samples were taken from a single crystal of FeS, characterized mineralogically by XRD and a hole was cut in order to hang them in the TGA apparatus. The designation for the samples is CMNH-Pyr-R3u 5h, CMNH-Pyr-R3u 15h, and CMNH-Pyr-R3u 20h. The mass for each of the samples that were run during the exposure of 15-20 hours is 0.29667g, 0.38003g, and 0.33166g respectively. Therefore the mass loss in-creases with length of exposure showing that the pyrite-pyrhotite phase change progresses regardless of the effects of texture and shape.

III. Methods

The TGA (Thermal Geometric Analysis) is an apparatus for measuring mass as a function of time under specific atmospheric flow conditions. For Venus approximately 94% of the atmosphere is CO₂, the sample and a platinum hook was attached to a quartz rod and a platinum chain inside a quartz tube. This apparatus was balanced with separate metal weights that were also under vacuum during the experiment. The tube was then evacuated twice and the pyrite sample was subjected to a CO₂ atmosphere at a rate of 400 cm³/min at 1 atm. Temperature was then raised incrementally to typical Venus surface temperatures (400°C). The mass, temperature, and duration was monitored throughout the experiment and recorded in realtime every 10 seconds during the experiment. Any mass of mass is attributed to an oxidizing reaction of the pyrite (and other minerals) as a result of the heat and CO₂ flow.

IV. Data

Each of the samples was retrieved from the TGA intact and mass loss is attributed to discrete dust-sized particles being removed as a result of an increase in volume due to the creation of another sulfide mineral. XRD analysis of the surface of the new material shows that it is pyrrhotite, a Fe₁₋ₓ S mineral. This mineral is a darker color than the pyrite and discolors the specimens. The final masses for each of the specimens in order of increased length of exposure from 15-20 hours are 0.29667g, 0.38003g, and 0.33166g respectively. Therefore the mass loss is similar in magnitude and on average is 0.00217g, 0.00292, and 0.00474g respectively. The post surface area measurements are 1.406 cm², 3.03 cm², and 1.279 cm². This means that the surface area loss is less than the sample and it is in between the 5 and 20 hour run. In each case the general shape of the sample remains even though the texture and color of the sample is much different. These exposures however are shorter than the ones that are proposed for the GEAR chamber under the full Venus conditions which could force this reaction to increase or decrease in rate as well as product which might be other than pyrrhotite. Preliminary results show mass loss on olivine and diopside even at 1 bar which was not foreseen. Further chemical modeling is necessary to pinpoint the mechanisms and reactions that are occurring during exposure. The inclusion of SO₂ at 180 ppm (detected abundance in the Venusian atmosphere) will offer further insight into these oxidation reactions.

V. Discussion

The conversion of pyrite (FeS₂) to pyrrhotite (Fe₁₋ₓ S) and then Fe oxides in a hot CO₂ atmosphere (such as found at the surface of Venus) is both known and predicted from prior work; yet the relative importance of this reaction remains controversial. More recent studies suggest this reaction can play a key role in buffering the abundance and oxidation state of S in that planet’s atmosphere, which can differ dramatically with altitude. Our experiments illustrate that there are some discrepancies that can occur through length of exposure suggesting mineral textures and volume changes can play key roles. Pyrrhotite was also the only major product of our experiments which was verified with XRD. The cracks in the samples, especially in R15 h, are most likely due to volume changes associated with newly-formed minerals. It is most likely more evident in this sample because of the largest increase in surface area 0.6638cm². The sample with the decrease in surface area is R13 u 5h (Figure 2) and this sample also has the most sample texture of the on the backs of the sample whereas R15 h and R12 h are the smoothest. The heaviest sample is the R15 u sample (Figure 4) and this sample fell in between the two extremes of the differences of rate. The difference in rate is similar in magnitude and an average is 0.03 mg/hour. The mass loss increases with length of exposure showing that the pyrite-pyrhotite phase change progresses regardless of the effects of texture and shape.

VI. Further Work

The depth and chemical profile of this reaction within the changes will be examined by SEM and EB. Other volcanic minerals such as olivine, pyroxene and feldspar are also going to be analyzed before exposure in the GEAR chamber under the full Venus conditions which could force this reaction to increase or decrease in rate as well as product which might be other than pyrrhotite. Preliminary results show mass loss on olivine and diopside even at 1 bar which was not foreseen. Further chemical modeling is necessary to pinpoint the mechanisms and reactions that are occurring during exposure. The inclusion of SO₂ at 180 ppm (detected abundance in the Venusian atmosphere) will offer further insight into these oxidation reactions.