I. Introduction

Measurements of Venus surface chemistry suggest a basaltic composition with a predominantly CO₂ atmosphere. In order to understand the reactivity of certain possible mineral species on the surface, previous simulation chambers conducted experiments at 1 atmosphere with simplified CO₂ atmosphere. Following this procedure, pyrite (FeS₂) samples are used to estimate the reactivity of sulfide minerals under a Venusian atmosphere and climate. Sulfur-rich gas species have been identified and quantified in the Venus atmosphere, and sulfurous 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 GEER chamber at NASA Glenn Research Center that can simulate pressure along with temperature and a more inclusive and representative Venusian atmosphere.

II. Samples

Figure 1: Samples of pyrite were supplied from the Cleveland Museum of Natural History. The three samples prepared for TGA analysis were taken from a single crystal of Fesn, characterized mineralogically by XRD and a hook was cut in order to hang them in the TGA apparatus. The dimensions of the samples were R3u 15h, 2.460 cm, R3u 10h, 1.03 cm, and R3u 5h, 0.53 cm. The mass of each of the samples was verified with XRD. The cracks in the samples, especially in R3u 15h, are the heaviest sample is the R3u 15h 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 on average is 0.3 mg/hour. The mass loss increases with length of exposure showing that the pyrite-pyrhottite phase change progresses regardless of the effects of texture and shape.

III. Methods

The TGA (Thermal Gravimetric 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 (1). 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 atmosphere. Temperature was then raised incrementally to typical Venus surface temperatures (470°C). The mass, temperature, and duration was monitored throughout the experiment and recorded in realtime every 10 seconds during the experiment. Any loss 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₋ₓS mineral. This mineral is a darker color than the pyrite and discolors the specimen. The final masses for each of the specimens in order of increased length of exposure from 5-15 hours are 0.2067g, 0.3880g, and 0.3316g respectively. Therefore the mass loss is 0.0022g, 0.0052g, and 0.0049g respectively. The post surface area measurements are 1.406 cm², 3.032 cm², and 1.279 cm². This means that the surface area difference for the respective samples is -0.789 cm², -0.586 cm², and 0.011 cm². There was a loss of surface area for the 5 hours exposure but the two other runs show an increase by varying amounts. The rates of each of the reactions were similar however they were not equal (Figure 7). The largest difference is between the R3u 5h run and the R3u 20h run although they have the most similar mass. The R3u 15h run has the largest mass and its rate 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 GEER chamber at NASA Glenn Research Center which are on the order of days/weeks. There is an increase between 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.

V. Discussion

The conversion of pyrite (FeS₂) to pyrrhotite (Fe₁₋ₓS) 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 (2). 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 (3). 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 R3u 15h, are most likely due to volume changes associated with newly-formed minerals. It is most likely more evident in this sample because underwent the largest increase in surface area 0.6638 cm². The sample with the decrease in surface area is R3u 20h (Figure 5) and this sample also has the most surface area of the on the backside of the sample whereas R3u 15h and R3u 5h are the smoothest. The heaviest sample is the R3u 15h 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 on average is 0.3 mg/hour. The mass loss increases with length of exposure showing that the pyrite-pyrhottite 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 EDS. Other volcanic minerals such as olivine, pyroxene and feldspar are also going to be analyzed before exposure in the GEER 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 pyrrhotite. Preliminary results show mass loss on olivine and deserve even at 1 bar which was not forsaken. Further chemical modeling is necessary to propose the mechanisms and reactions that are occurring during exposure. The injection of SO₂ at 180 ppm (detected abundance in the Venusian atmosphere) will offer further insight into these oxidation reactions.