Alumina is a common protective oxide and a component of proposed oxide/oxide composite and high temperature coating systems. Many of these applications require stability in combustion environments that contain water vapor. The volatility of alumina in water vapor is therefore of interest.

Formation of volatile aluminum hydroxides in combustion environments is proposed to occur by the following reaction:

$$\text{Al}_2\text{O}_3(s) + \frac{3}{2} \text{H}_2\text{O}(g) = \text{Al(OH)}_3(g) \quad (1)$$

Thermochemical data for the Al(OH)$_3$(g) species have been calculated by statistical methods using partition functions based on the properties of like molecules [1]. Experimental data for the above reaction has also been obtained indirectly by the transpiration method using water vapor and calcium aluminates [2]. The objective of this work is to obtain experimental evidence for reaction (1) above, directly from alumina using a coupon weight loss technique.

Weight loss of sapphire coupons (001 orientation, flame fusion grown, <100 ppm impurity, General Ruby and Sapphire Corporation, New Port Richey, FL) in water vapor/oxygen mixtures was measured by suspending the specimens from a sapphire hanger in a thermogravimetric vapor/oxygen mixtures was measured by suspending the specimens from a sapphire hanger in a thermogravimetric apparatus, described in a previous paper [3]. The specimens were obtained indirectly by the transpiration method using water vapor and calcium aluminates [2]. The objective of this work is to obtain experimental evidence for reaction (1) above, directly from alumina using a coupon weight loss technique.

The weight change obtained from initial and final weights of the sapphire coupons was used to calculate the partial pressure of the volatile species, $P$, assuming Al(OH)$_3$(g) formation:

$$w = 0.66 \left( \frac{\rho}{\eta} \right)^{1/2} \left( \frac{\eta}{\rho D} \right)^{1/2} \frac{v}{L} \frac{A}{t}$$

where $w$ is the coupon weight change, $A$ is the surface area of the test coupon, $t$ is the exposure time, $\rho$ is the gas density, $\eta$ is the gas viscosity, $D$ is the interdiffusion coefficient of the volatile species in the laminar gas boundary layer, $M$ is the molecular weight of the volatile species, $R$ is the gas constant, and $T$ is the test temperature.

Results for the temperature dependence of alumina volatility obtained in 0.5 atm $\text{H}_2\text{O}$/0.5 atm $\text{O}_2$ are shown in Figure 1. A reaction enthalpy for Equation (1) of $210 \pm 20$ kJ/mol is obtained from the results. This value is in good agreement with those found in the literature.

The dependence of alumina volatility on water vapor partial pressure at 1450°C is shown in Figure 2. A power law exponent of 1.55 ± 0.11 is obtained. These results are consistent with the power law exponent of 3/2 that is expected for formation of Al(OH)$_3$(g) by Equation (1).

Scanning electron micrographs showing preferential surface etching caused by the volatility reaction will also be presented.