

ALUMINA VOLATILITY IN WATER VAPOR AT ELEVATED TEMPERATURES

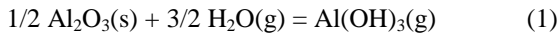
Elizabeth J. Opila,* Dwight L. Myers&

*Cleveland State University, Cleveland, OH 44115

&East Central University, Ada, OK 74820

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:



Thermochemical data for the $\text{Al}(\text{OH})_3(\text{g})$ 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 analysis apparatus, described in a previous paper [3]. The Al_2O_3 volatility was measured at temperatures between 1250 and 1500°C, water vapor partial pressures between 0.15 and 0.68 atm, one atm total pressure, a gas velocity of 4.4 cm/sec, and times between 47 and 240 hours.

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 $\text{Al}(\text{OH})_3(\text{g})$ formation:

$$\frac{\Delta w}{A t} = 0.664 \left(\frac{\rho' v L}{\eta} \right)^{1/2} \left(\frac{\eta}{\rho' D} \right)^{1/3} \frac{\text{DPM}}{\text{LRT}} \quad (2)$$

where Δw is the coupon weight change, A is the surface area of the test coupon, t is the exposure time, ρ' is the gas density, v is the gas velocity, L is a characteristic length of the coupon, η 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 O_2 are shown in Figure 1. A reaction enthalpy for Equation (1) of 210 ± 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 $\text{Al}(\text{OH})_3(\text{g})$ by Equation (1).

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

References

1. L.V. Gurvich, I.V. Veyts, C.B. Alcock, Thermodynamic Properties of Individual Substances, Vol. 3., Part 1, pp. 138, 150-151, Part 2, p 115, Begell House, Inc., New York, 1996.
2. A. Hashimoto, "The Effect of H_2O Gas on Volatilities of Planet-Forming Major Elements: 1. Experimental Determination of Thermodynamic Properties of Ca-, Al-, and Si-Hydroxide Gas Molecules and its Application to the Solar Nebula," *Geochim. Cosmochim. Acta* 56, 511-32 (1992).
3. E.J. Opila, "Oxidation Kinetics of Chemically Vapor-Deposited Silicon Carbide in Wet Oxygen," *J. Am. Cer. Soc.*, 77 [3] 730-36 (1994).

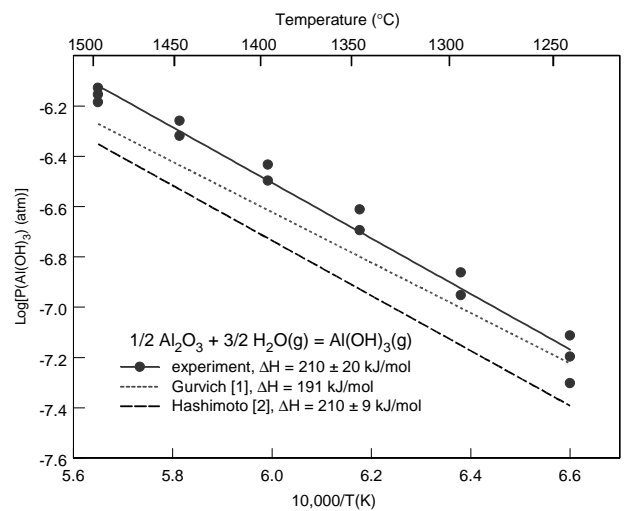


Figure 1. Temperature dependence of $\text{Al}(\text{OH})_3(\text{g})$ formation according to Reaction (1). Both experimental and calculated results are shown for sapphire at 0.5 atm $\text{H}_2\text{O}/0.5$ atm O_2 .

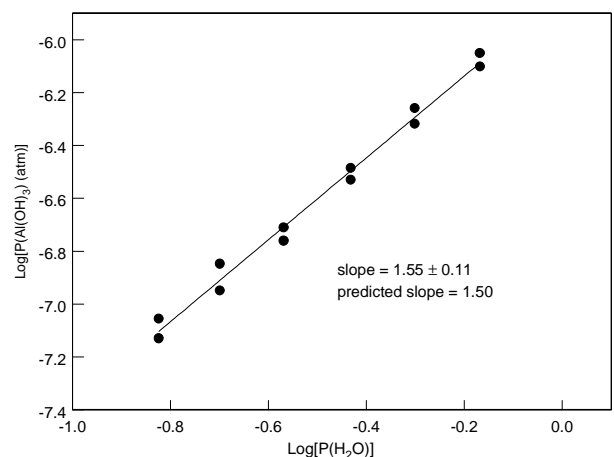


Figure 2. Water vapor partial pressure dependence of volatile Al-O-H species determined from weight loss experiments at 1450°C showing confirmation of expected power law dependence for $\text{Al}(\text{OH})_3(\text{g})$.