The Vapor Pressure of Palladium at Temperatures up to 1973K

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Introduction

Understanding high-temperature processes is imperative for modeling the formation of the solar system. It is unfortunate that since the 1950's little has been done in the area of thermodynamics to continue gaining information on metals such as iron (Fe), nickel (Ni), cobalt (Co), palladium (Pd) and many others. Although the vapor pressure of these metals can be extrapolated to higher temperatures, the data is limited to temperature ranges too low to be analogous to the formation of the solar system (T ~2000K). Experimental techniques inhibited the data in the past by restricting the testing of metals past their melting point. Today, that testing is possible by using a Thermo-Cahn Thermogravimetric system that is able to reach temperatures up to 1973K in vacuo and measure a 10 gram change in a sample with mass of up to 100 grams.

Problem

Since the walls of our cell have finite thickness and the vapor lost through the hole requires replacement from the metallic liquid reservoir to maintain equilibrium, correction factors must be applied to our new mass loss data.

1. *Pipe Correction Factor (K):* It is a pipe, not an infinitely thin wall.

$$K = \frac{1}{1+0.5(L/R)} \qquad K = \frac{1+0.4(L/R)}{1+0.95(L/R)+0.15(L/R)^2}$$

1.5 > (L/R) > 0 *(L/R) > 1.5*

L = wall thickness R = radius of the hole

For this work, (L/R) < 1.5, so the first equation is used.

2. *Disequilibrium Correction Factor (σ):* Equilibrium is disrupted as vapor exits.

$$\sigma = \frac{1}{1+\frac{aK}{A\alpha}}$$

a = area of the evaporating material
α = evaporation accommodation coefficient
(For Palladium, α = 1)

Using these two corrections, the correct vapor pressure calculation is:

$$P_{corrected} = \frac{P}{\sigma K}$$

P = Pressure calculated from the Ideal Gas Law assuming infinitely thin wall

Why Palladium?...

...It is an excellent standard!

- ✓Noble metal
- ✓Monomeric mass loss
- ✓Does not readily react with anything in the system
- ✓Vapor pressure is reasonably well determined up to its melting point and somewhat beyond
- ✓Will ensure accuracy of high-temperature data for Ni, Fe, Co

46
Pd
Palladium
106.42

Experimental Procedure

Construction of Effusion Cell

1) Obtain 2 closed-end alumina tubes—one 6mm and one 10 mm in diameter (see Figure 1)
2) Cut each tube to appropriate length
3) Drill small effusion hole at closed end of the smaller-diameter tube
4) Measure the diameter of effusion hole with graduated drill bits
5) Insert small tube, open end first, into the large tube
6) Seal the tubes with zirconia adhesive

Figure 1: Effusion Cell for Measuring Vapor Pressure
Outside diameter of cell is 10mm
Effusion Hole diameter is 1.27mm

Testing

1) Insert the effusion cell into the Thermo-Cahn system (see Figure 2)
2) Program a series of temperature and time periods for the measurements
3) Heat to 473K for 1 hour and then 973K for several more hours to remove volatiles
4) Start the run
5) Record cell mass and temperature at the rate of one measurement per second

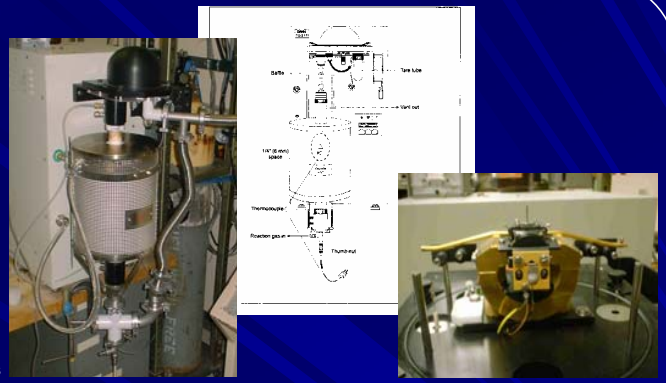

Figure 2: Thermogravimetric System and Electronic Balance

Results and Discussion

My measurements of the vapor pressure of Pd are shown in Figure 3. The blue line represents previously determined vapor pressures of Pd by Hultgren et al, extrapolated up to about 2000K. Figure 4 contains current measurements of Fe, Ni and Co.

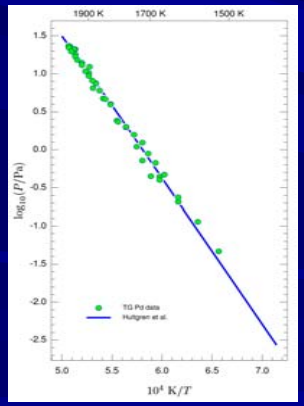

Figure 3: Pd Vapor Pressure Data

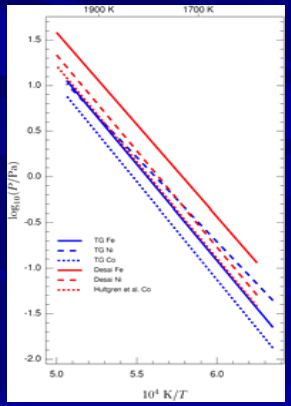

Figure 4: Fe, Ni, Co Vapor Pressure Data

Our measurements match those of Hultgren et al.
The system is correct!

My Contribution

- ✓My study of Palladium proved that the Thermo-Cahn system provides valid data up to 1973K.
- ✓More metals can now be measured with higher confidence in the temperature range of protostellar nebulae.
- ✓NEXT STEP: Measure vapor pressures of various silicates up to 1973K.

Applications to Natural Systems

- ✓Condensation processes in the early solar nebula and circumstellar outflows
- ✓Evaporation of grains in the innermost solar nebula
- ✓Condensation processes in newly-forming protostellar systems

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