PALOMAR COLLEGE
ENGINEERING 245

VOLUME CHANGES DUE TO ALLOTROPIC TRANSFORMATION

Iron changes from BCC crystal lattice structure (alpha iron) to FCC structure (gamma iron) at about 910 C. This allotropic transformation can be verified experimentally. Measured data can be compared to theoretical calculations.

Measure the change in length of a piece of iron wire as the transition occurs from alpha to gamma iron. From the length change find the experimental volume change:

$V = \pi r^2 \ell$ Differentiating, $dV = \pi r^2 d\ell + 2\pi \ell r dr$

Dividing by V, $\frac{dV}{V} = \frac{\pi r^2 d\ell}{\pi r^2 \ell} + \frac{2\pi \ell r dr}{\pi r^2 \ell} = \frac{d\ell}{\ell} + 2\frac{dr}{r}$

If the material is isotropic, $\frac{d\ell}{\ell} = \frac{dr}{r}$

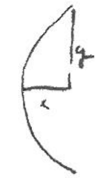
Therefore, $\frac{dV}{V} = 3\frac{d\ell}{\ell}$ (or - the relative volume change is three times the relative length change)

I Suspend a loop of ordinary soft iron wire (about 99.5 % Fe, with a zinc coating which may be ignored) about a meter long between two ring stands. Attach the two ends to a variable transformer so the wire can be heated electrically. Use a steel rule to measure the bottom of the loop (see sketch on the next page).

Compare the length change observed with that expected from theoretical bases. Use the lattice constants given in the previous experiment. Be sure to take into account that the BCC unit cell contains two atoms, while the FCC unit cell contains four atoms.

Compare the observed change in length due to thermal expansion with that calculated from data provided in a handout, taken from the literature. Assume that the microstructure consists of pure alpha iron from room temperature to 910°C, and then changes abruptly and completely to gamma iron. (Note: since the coefficients given do not vary in linear fashion, you can't average them. It's easiest to calculate expansion in a series of steps which can then be summated).

II Experimental Observations



Using either $a = \sqrt{4x^2+y^2} + \frac{y^2}{2x} \ln\left[\frac{2x + \sqrt{4x^2+y^2}}{y}\right]$

[Source: Handbook of Chemistry and Physics]

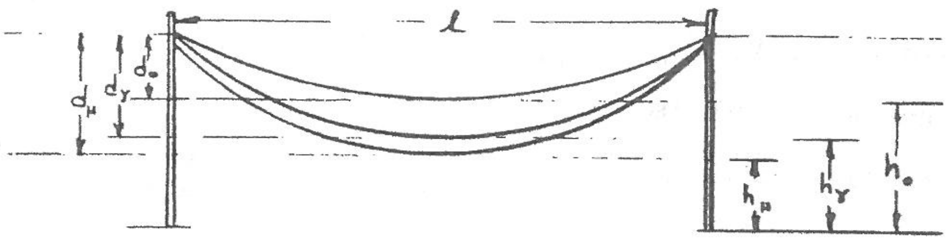
or $a = l\left[1 + \frac{2}{3}\left(\frac{2d}{l}\right)^2\right]$

[Source: Burington's Handbook of Math. Tables]

calculate arc lengths and compare.

DATA

Raw Data: Explain measurements clearly, with reference to a sketch; summarize and tabulate.



Reduced Data: Tabulate arc lengths, differences and percent differences so that results can be compared to those expected from theoretical bases.

a_o	a_μ	a_γ	Δa_μ	$\% \Delta a_\mu$	Δa_γ	$\% \Delta a_\gamma$

DISCUSSION

Thermal expansion is usually greater than the expected or theoretical expansion. Perhaps the heated wire is stretching? The data does not reveal whether the wire returns to its orginal length when it cools. Perhaps the thermal expansion coefficients given are not reliable.

Allotropic change in length is in good agreement with theoretical expectations, IF the largest observed transitions are used for calculations. Since all experimental factors (non-uniform wire diameter, different transition times, heating change and phase transition occurring at the same time, uneven cooling) act to reduce the allotropic change observed, this seems a justifiable selection of data.

Observations were accurate, at best, to the nearest millimeter. Since we were working with small differences between lengths in the 100 + cm range, this required calculations to at least five digits.