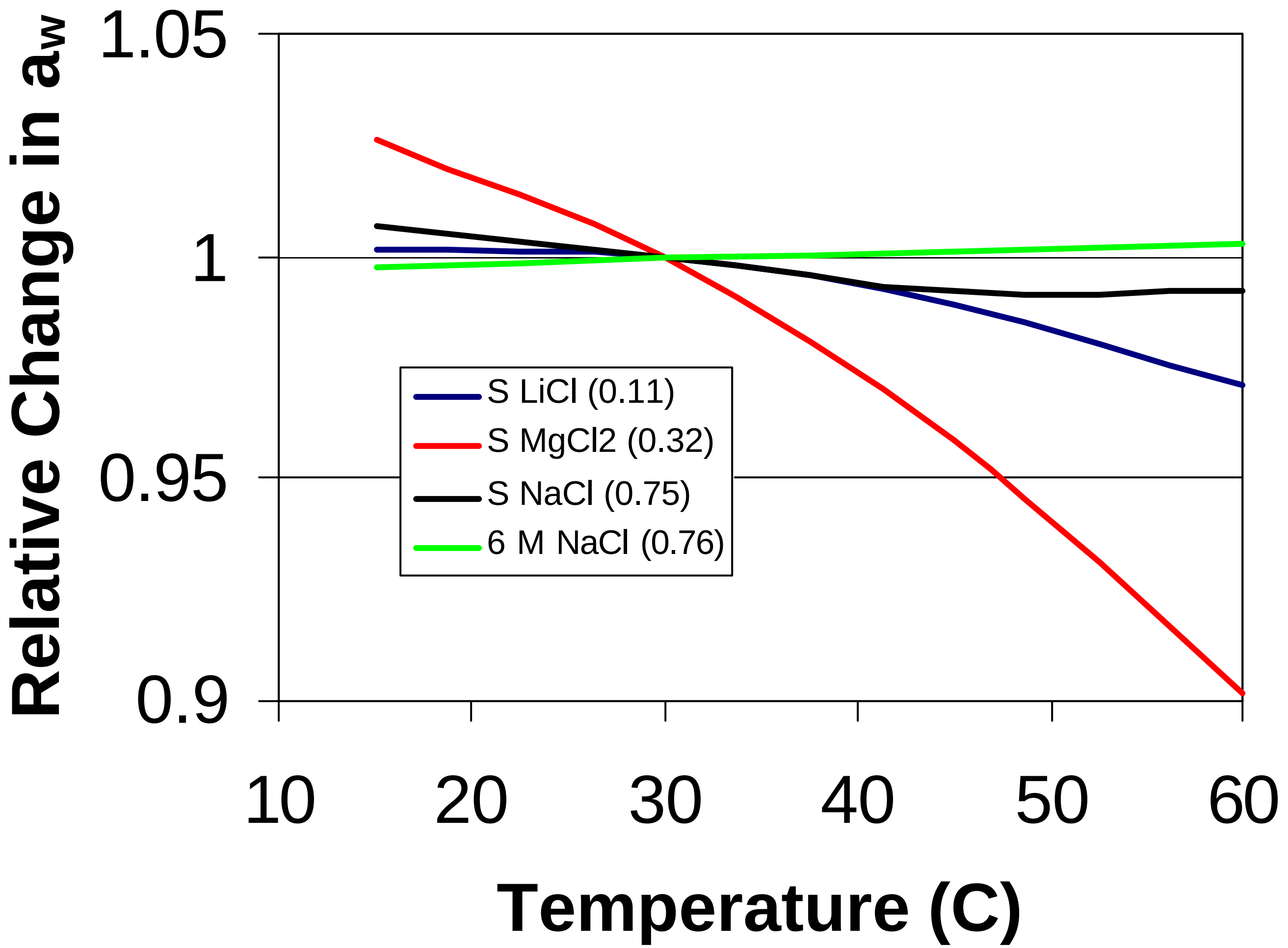
Heat of Sorption Measured using a Chilled Mirror, Dew Point Water Activity Meter

G. S. Campbell, E. M. Huffaker, and A. J. Fontana

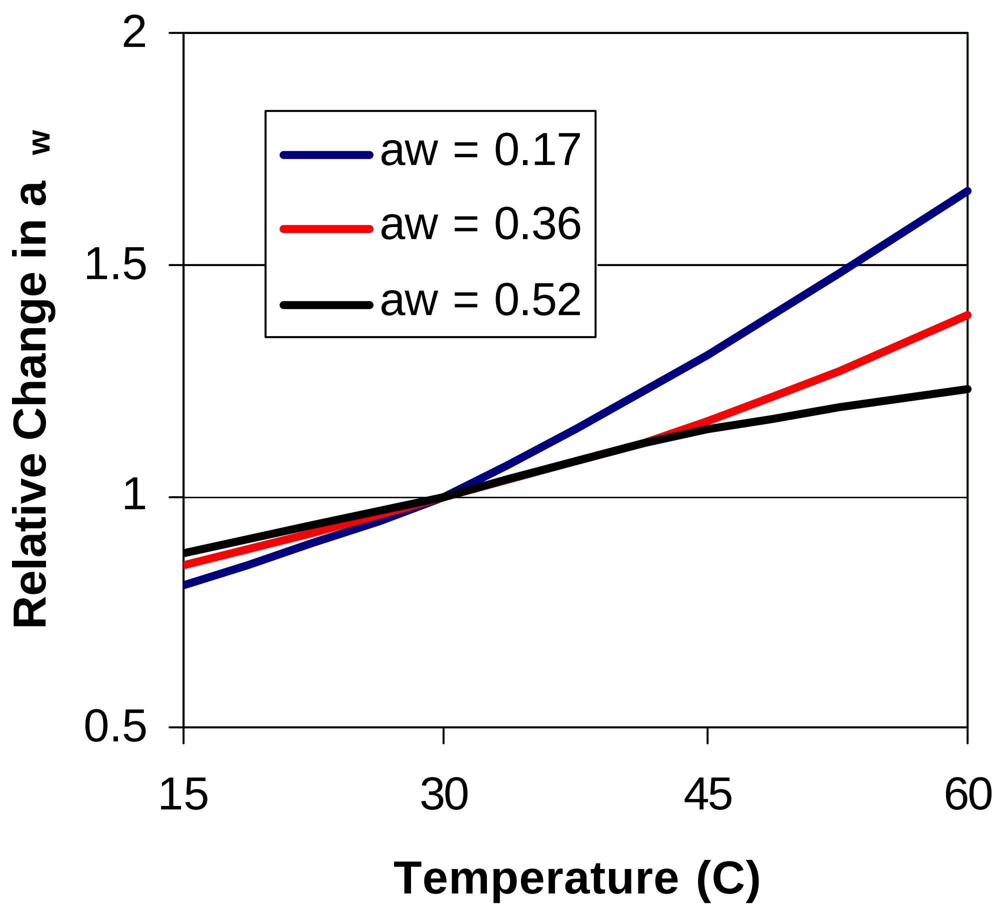
Decagon Devices, Inc.

Pullman, WA USA

Temperature Effects on Salts



Temperature Effects on Flour



Observations

- a_w change in flour > a_w change in salts
- Flour a_w increases with temperature
- The drier the flour, the greater the change
- Flour that is in a safe a_w range at one temperature may not be in a safe range at a higher temperature

Objectives

- Quantify temperature effects on water activity of a variety of food samples
- Determine heat of sorption for these samples for a range of water activity
- Relate heat of sorption to other thermodynamic properties of the samples

Experimental Material

- Wheat flour (white)
- ground corn
- milk powder
- ground mustard seed
- micro crystalline cellulose

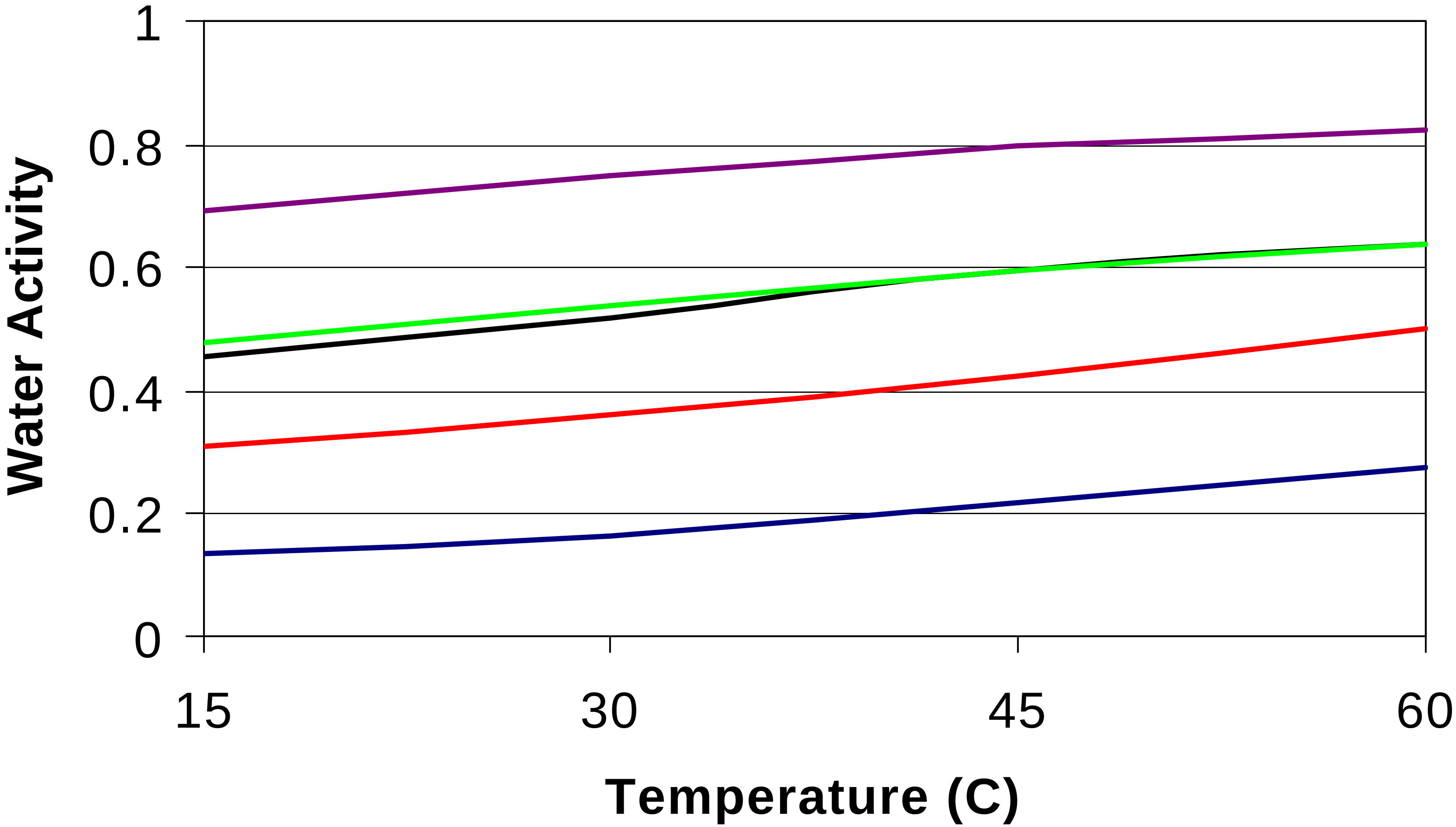
Measurements

- Vapor exchange over water or desiccant used to adjust water activity of samples between 0.1 and 0.7
- After equilibration, water activity was measured at 15, 30, 45 and 60 C

Chilled-Mirror Dew Point Measurement of a_w

- Typical temperature sequence was low to high
- Some samples went low to high to low

Wheat Flour (white)



Finding Heat of Sorption

$$\ln(a_w) = \frac{Q_s}{RT} + C$$

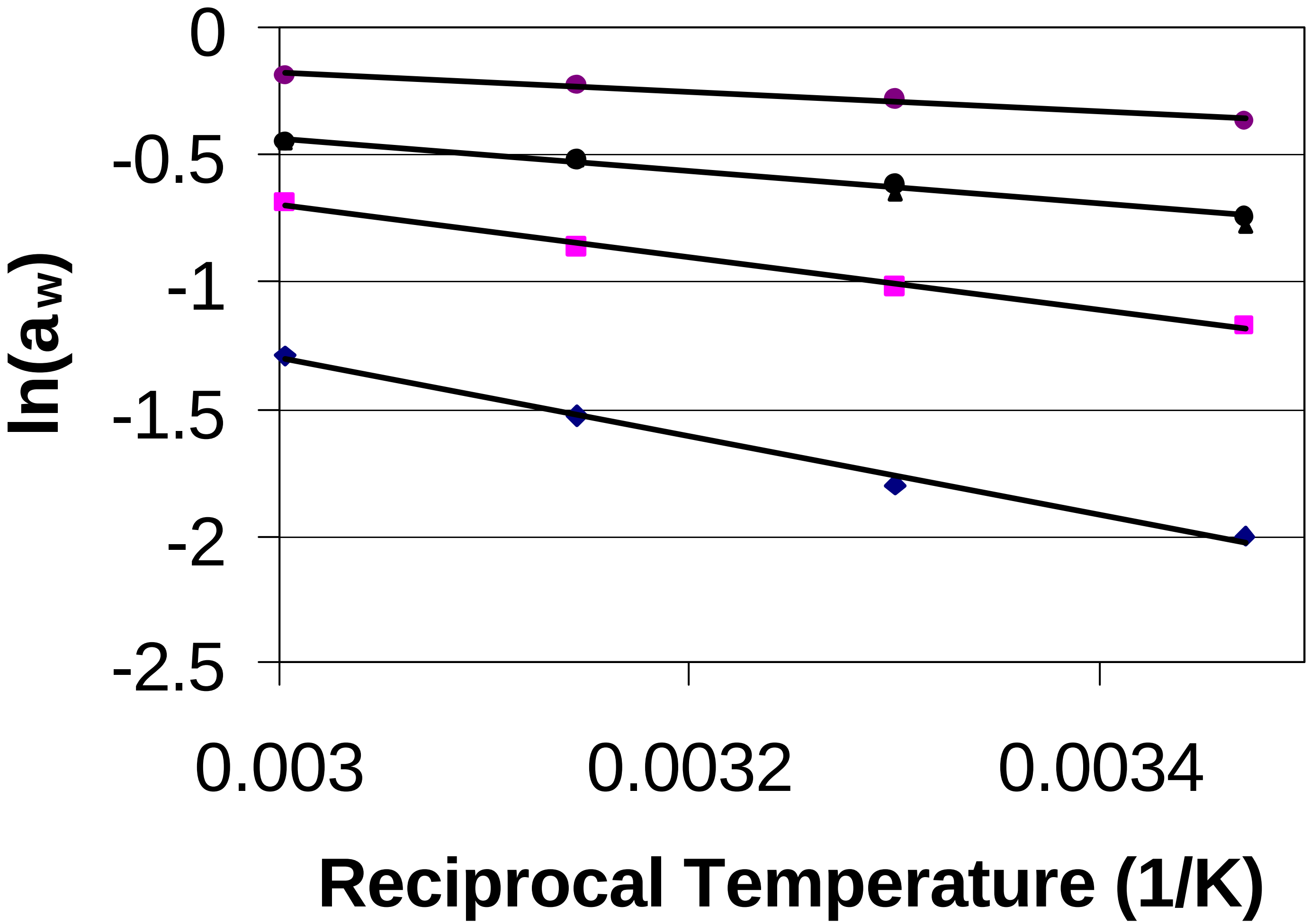
Q_s is heat of sorption

R is $8.31\, J\, mol^{-1}\, K^{-1}$

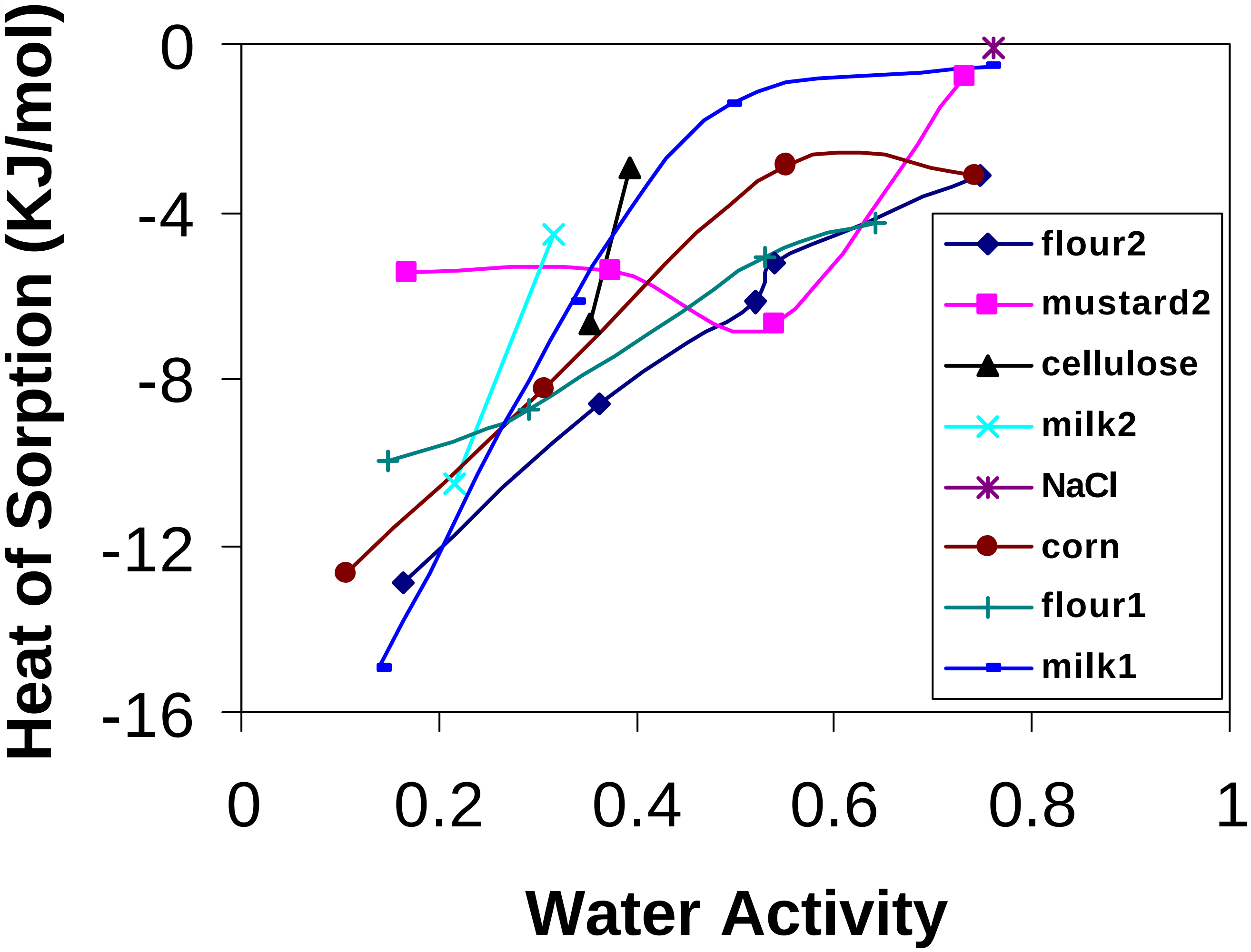
T is Kelvin temperature

Plot $\ln(a_w)$ vs. $1/RT$. Slope is Q

Plot to get Heat of Sorption



Heat of Sorption vs. Water Activity



Energy Status of Water

- Water activity is a relative measure of the energy status of water in a system
- Water potential is an absolute measure of that energy
- Water potential (J/mol) is related to water activity through:

$$y = RT\ln(a_w)$$

Energy Components

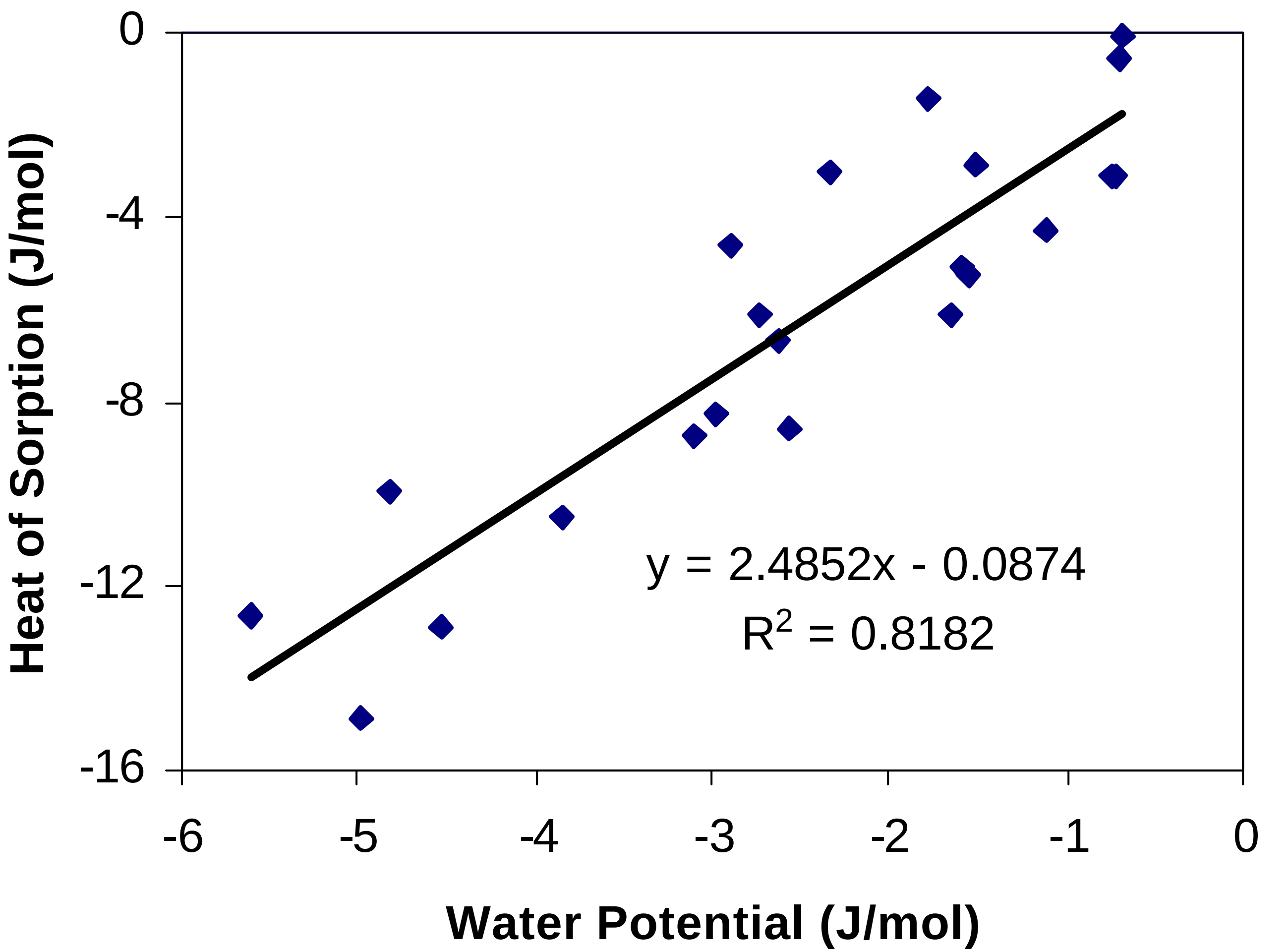
Energy status of water in food is affected by:

- van der Waals - London forces that bind water to surfaces (matric)
- dilution of water by solutes (osmotic)
- Pressure
- gravity

Is Heat of Sorption Related to Water Binding Forces?

	Qs/Ψ
Saturated NaCl	-0.4
Unsaturated NaCl	0.1
Wheat Flour	3.5

Predicting Heat of Sorption



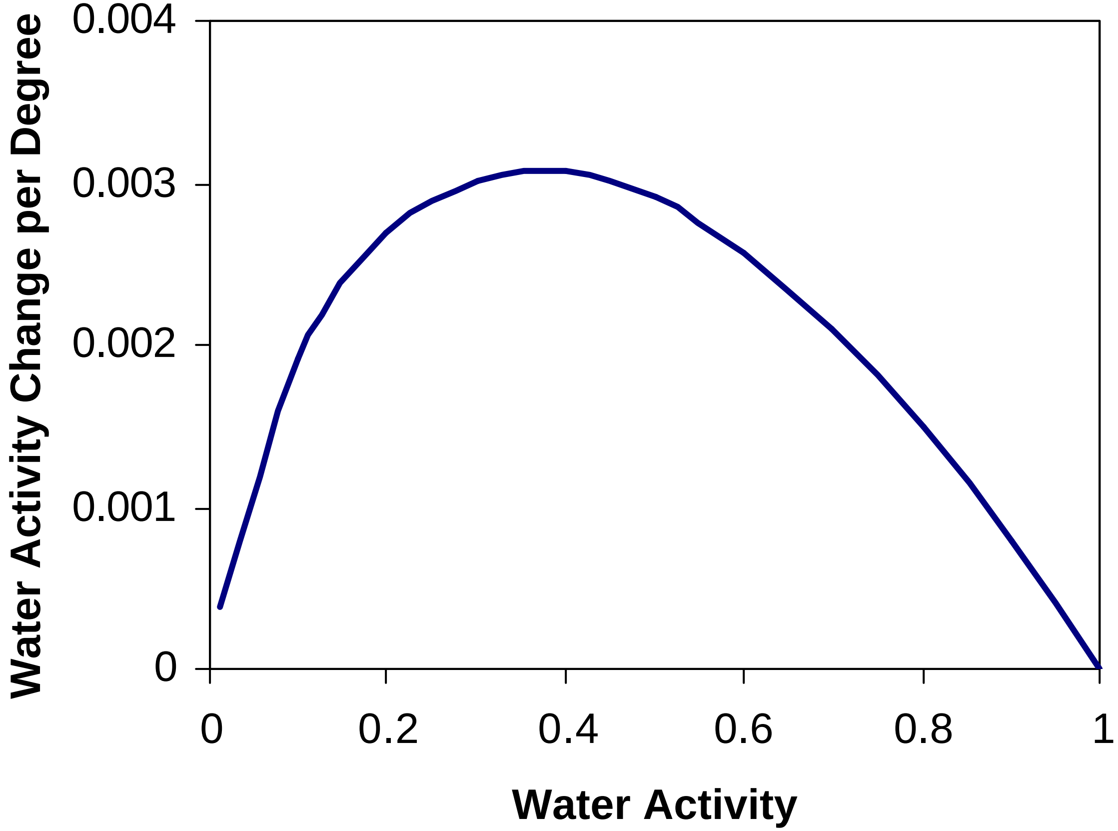
a_w Change with Temperature in Matrix Dominated Systems

$$Q_s = 2.5y \quad = 2.5RT\ln(a)$$

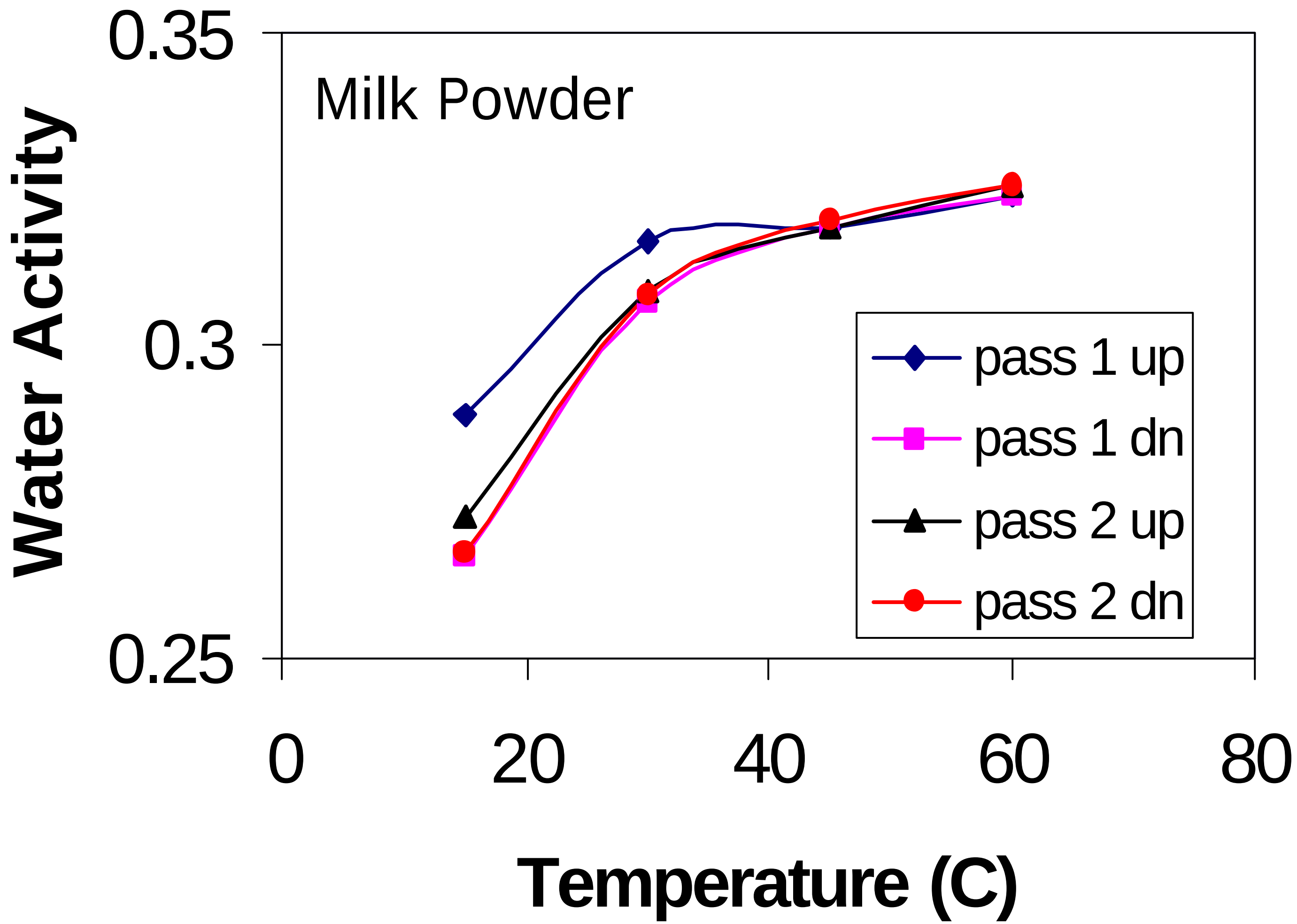
$$\ln(a_2 / a_1) = \frac{Q_s}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right) = 2.5\ln(a)\frac{\Delta T}{T}$$

$$a_2 = a_1 \exp\left(2.5\ln(a)\frac{\Delta T}{T}\right)$$

a_w Change with Temperature in Matrix Dominated Systems



Matrix Changes During Temperature Cycling



Conclusions

- A temperature controlled, chilled mirror device works well for quantifying temperature dependence of a_w
- Heat of sorption was strongly dependent on water activity, but relatively constant with temperature for the samples tested.

Conclusions

- For matrix dominated systems, heat of sorption is 2.5 times water potential
- Matrix changes during heating are easily tracked by subjecting samples to repeated heat-cool cycles.