PACKING OF SOFT SPHERES

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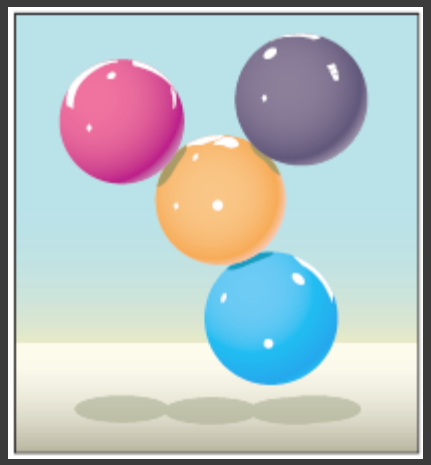
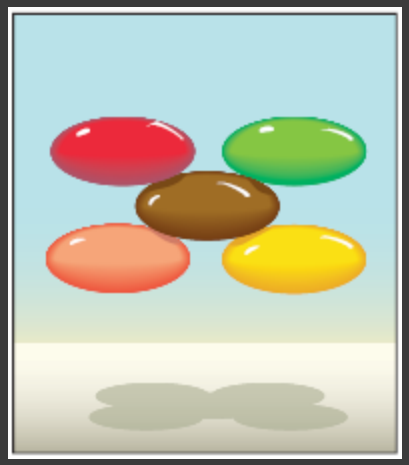
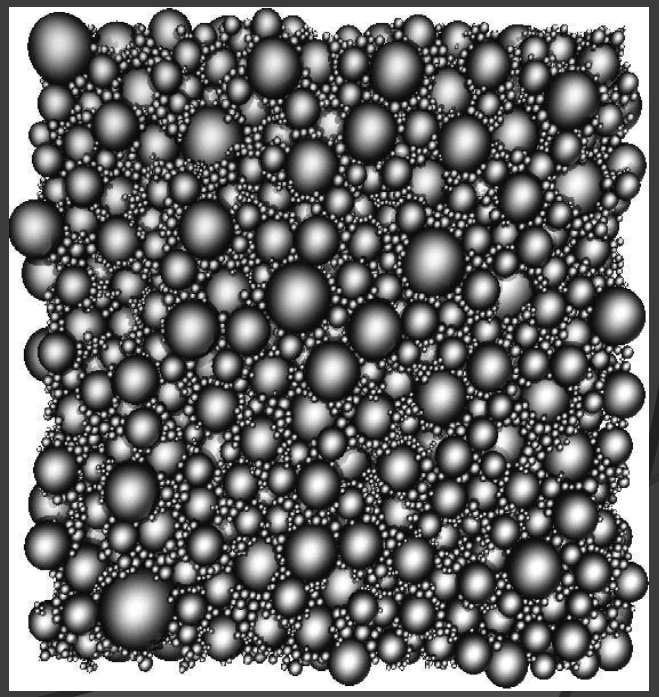
SURF 2009

What we studied

- Hard spheres vs soft spheres
- Monodisperse vs polydisperse
- High packing fraction







"Index of /images/scanner_art/." *Contemporary Digital Painting, Fine Art Prints of Flowers, Landscapes, Photography, & Abstracts.* Web. 30 July 2009. <http://www.blueberrycreek.com/images/scanner_art/>.
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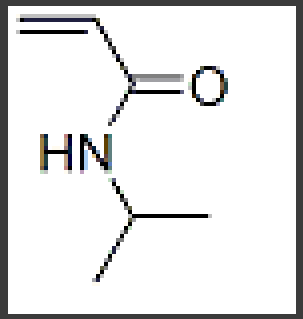
Weitz, David A. "Packing in the Spheres." *Science* 303 (2004): 968-69. Print.

Goals

- Effect of polydispersity at high packing fraction
- Model system of bimodal spheres
  - Different ratios of radius
  - Different fraction of each radius
  - Soft spheres

Why Poly-NIPAM

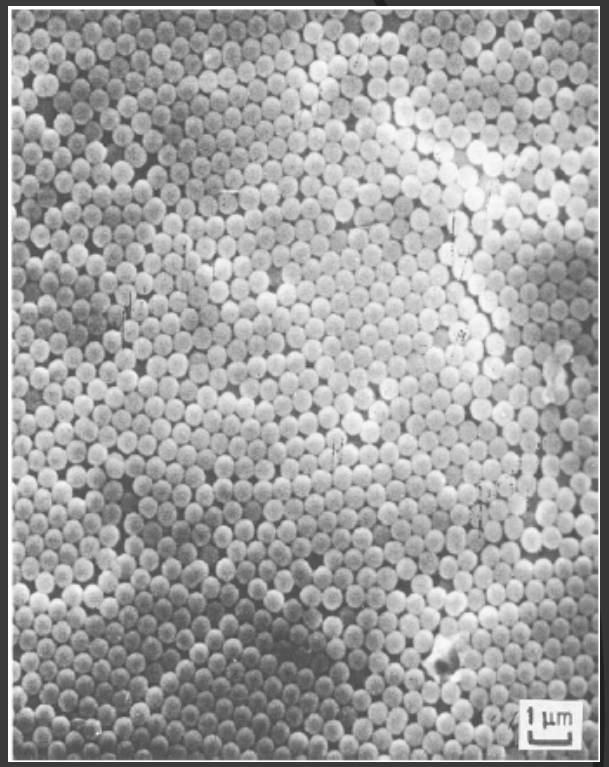


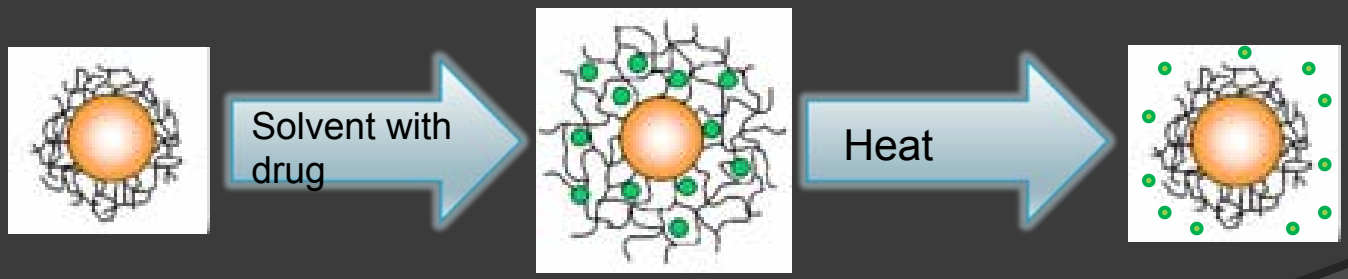
- Thermosensitive gel
- Hard and soft
- Easy to prepare controlled radius particles

T=20°C T=40°C

Applications

- Ceramics
- Glass
- Minerals
- Drug delivery vector





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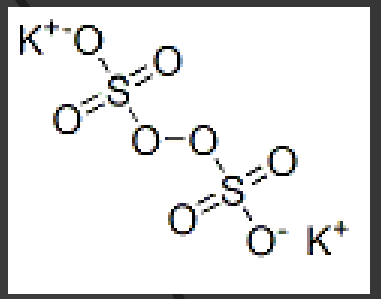
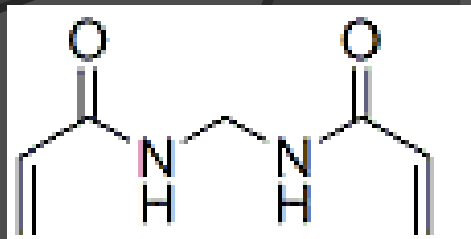
Microgel Particle Synthesis

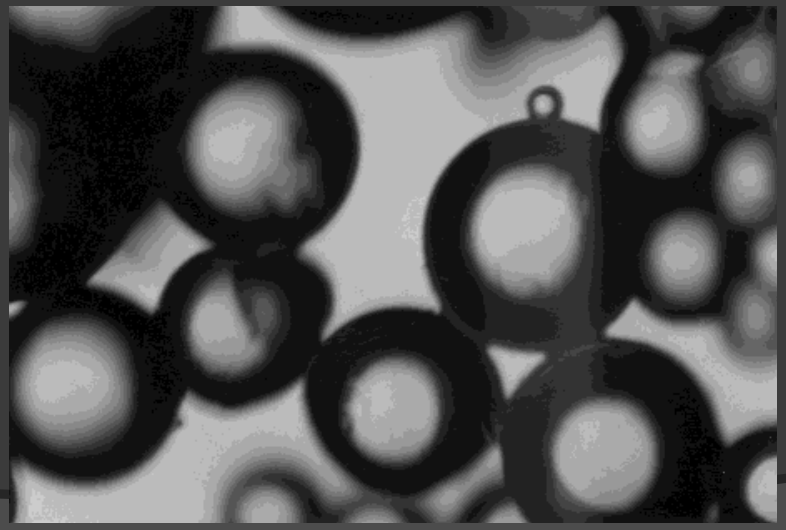


- Monomer *N*-isopropylacrylamide (NIPAM),crosslinker *N,N'*-methylenbisacrylamide (BIS), initiator potassium persulfate (KPS) in degassed aqueous solution
- Heat solution to 70°C, add KPS, stir 4-6 hours
- Amount of BIS controls swelling
- Amount of KPS controls radius



Characterization of Microgel Particles

- Dynamic Light Scattering (DLS)
- Small Angle Neutron Scattering (SANS)
- Ultra Small Angle Neutron Scattering (USANS)



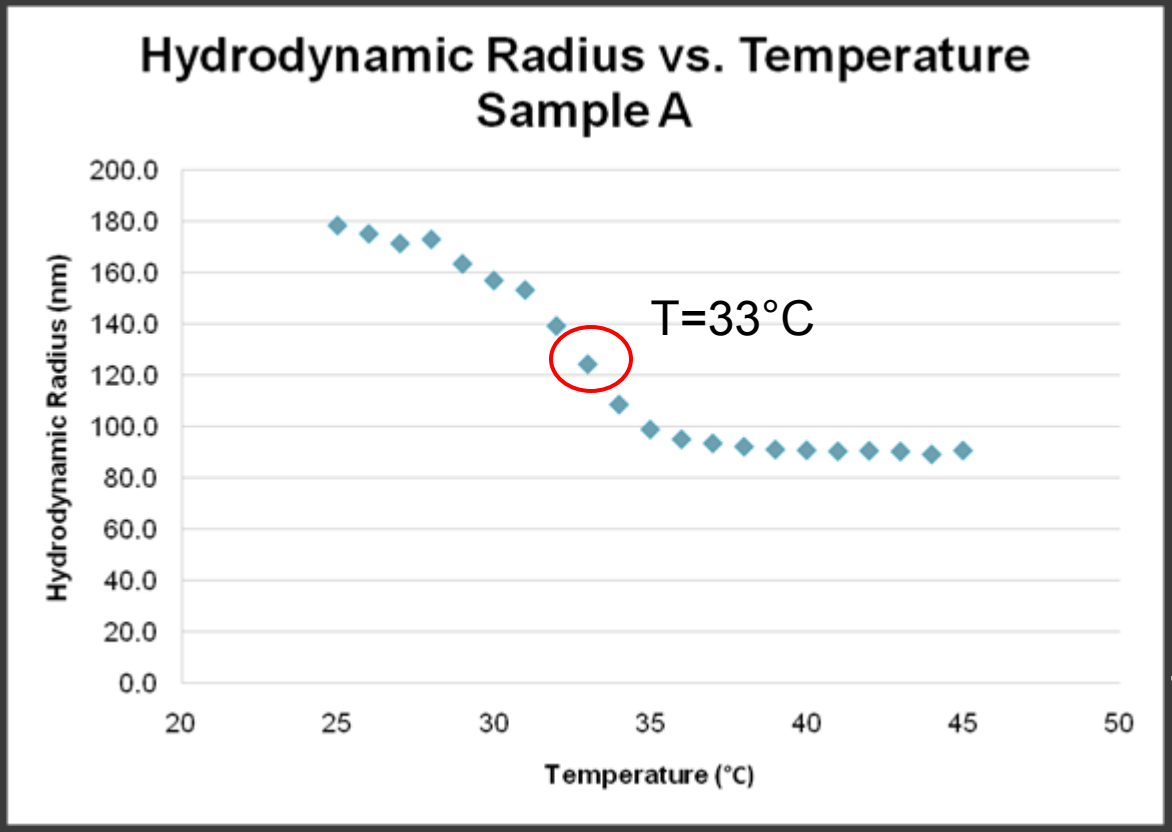
PNIPAM beads, magnification x40000

Kayaman, Nilhan, Dilek Kazan, Altan Erarslan, Oguz Okay, and Bahattin M. Baysal. "Structure and Protein Separation Efficiency of." *Journal of Applied Polymer Science* 67 (1998): 805-14. Print.

Dynamic Light Scattering

- Light passes through sample, fluctuations of intensity of scattered light are measured
- Yields diffusion coefficient
  - Stokes-Einstein equation, assuming spherical shape yields hydrodynamic radius
- Temperature scan
- Shows transition temperature (lower critical solution temperature, LCST)

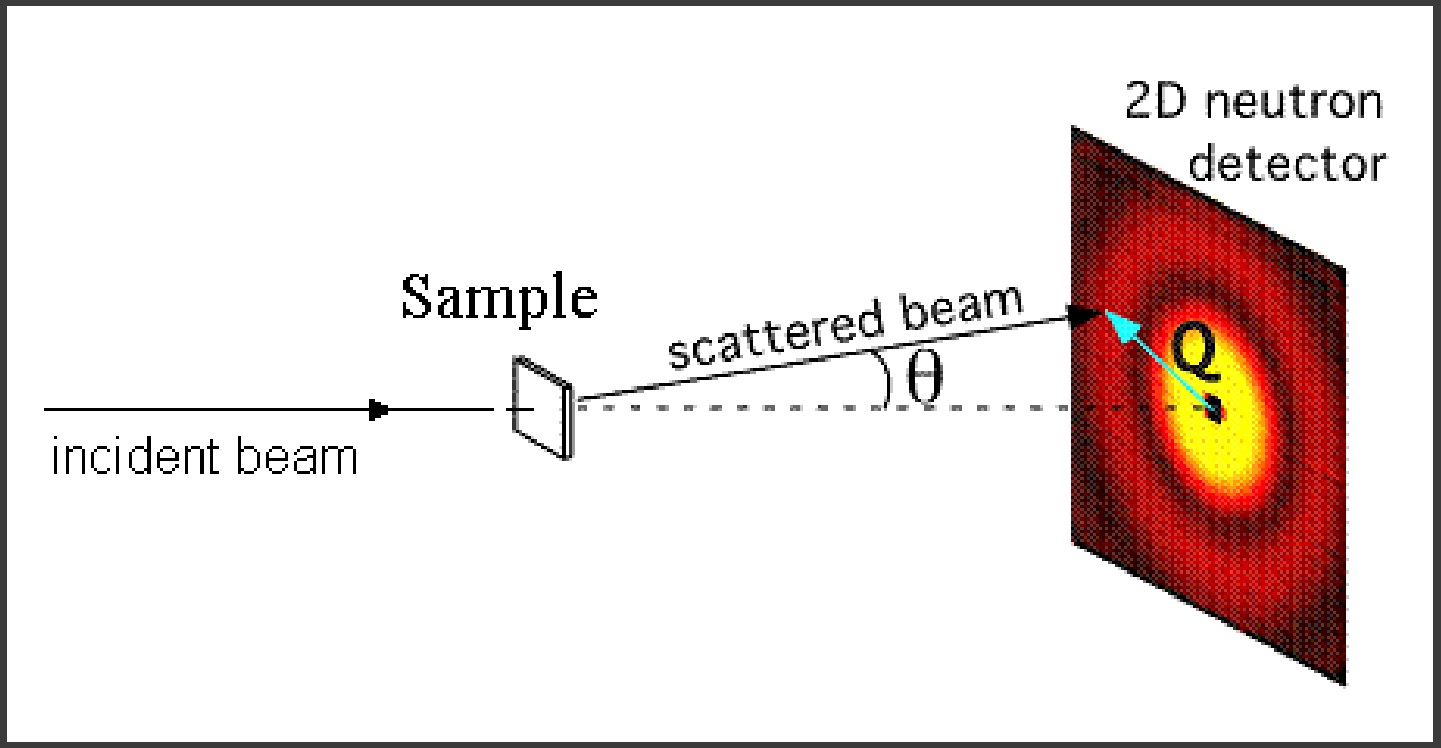
Dynamic Light Scattering



Temperature scan of sample A

- Transition temperature at 33°C
- Radius changes by a factor of 2

Small Angle Neutron Scattering

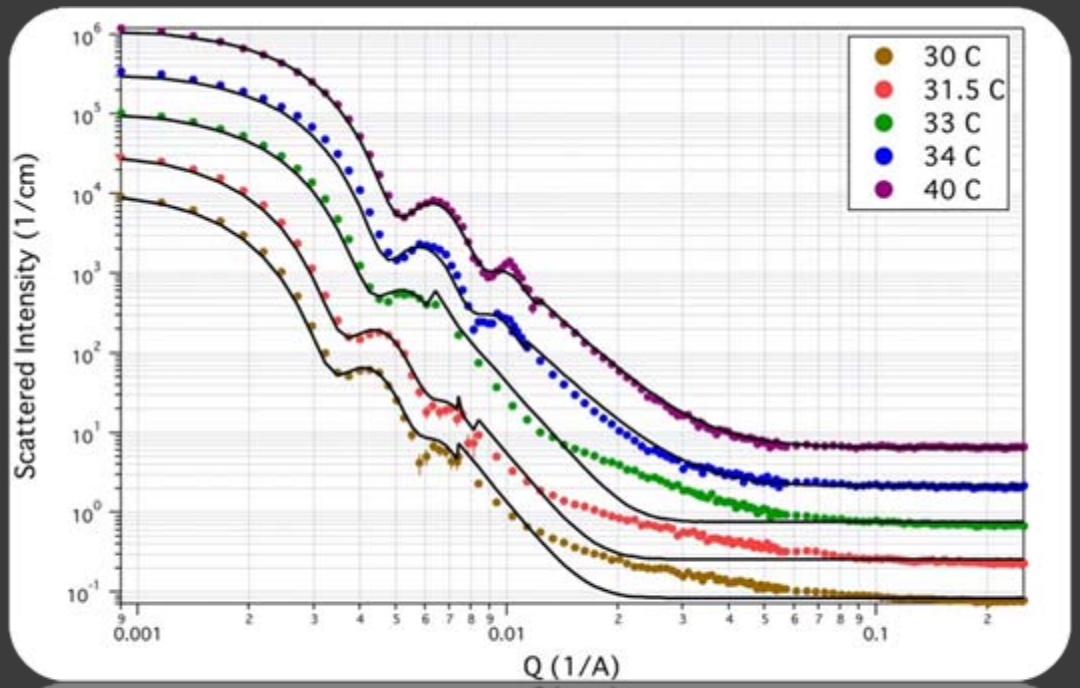


- 1 nm to 500 nm
- $Q=(4\pi/\lambda)\sin(\theta/2)$
- $D=2\pi/Q$

USANS
100 nm to 1000 nm

"NIST - Center for Neutron Research - Small-Angle Neutron Scattering Group." *NIST Center for Neutron Research*. Web. 30 July 2009. <http://www.ncnr.nist.gov/programs/sans/>.

SANS of Microgel vs Temperature



- Data at 40°C and 34°C are modeled using Schulz Spheres. Data at 33°C, 31.5°C, and 30°C are modeled using Fuzzy Spheres.

- Confirms that particles are spherical
- Shows change of radius

Temperature (°C)	Radius (nm)	Interface Thickness (nm)
30	134.6 ± 0.6	8.3 ± 0.3
31.5	126.2 ± 0.5	7.7 ± 0.1
33	104.1 ± 0.3	6.1 ± 0.1
34	96.0 ± 0.2	N/A
40	89.2 ± 0.2	N/A

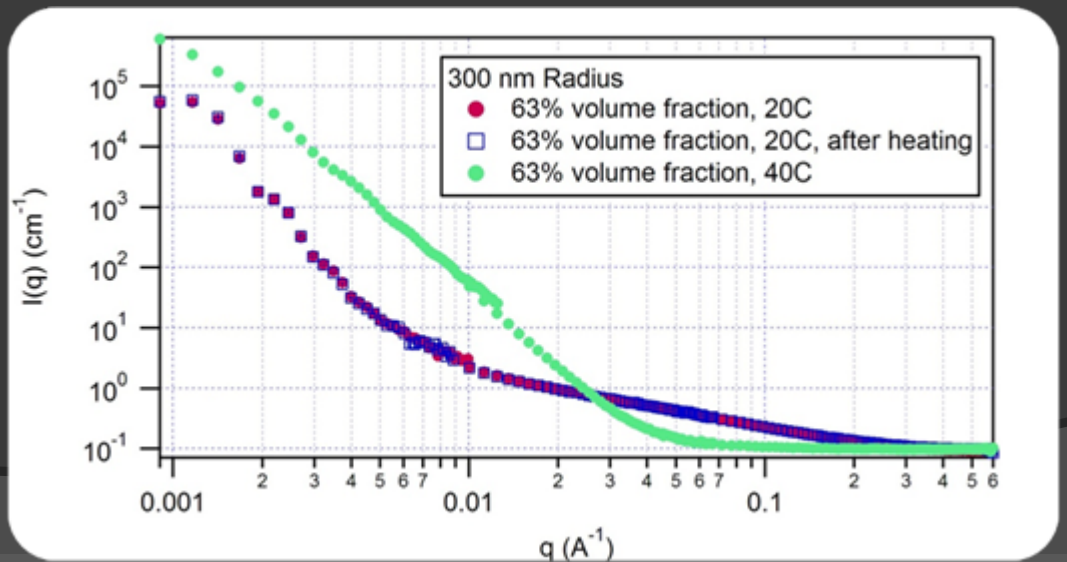
Last week...

- 2 large batches of microgel
- 2 radii: 150 nm and 300 nm
- 3 mixtures: total ϕ=0.70
  - 90/10 large/small
  - 70/30 large/small
  - 50/50 large/small
  - Individual components

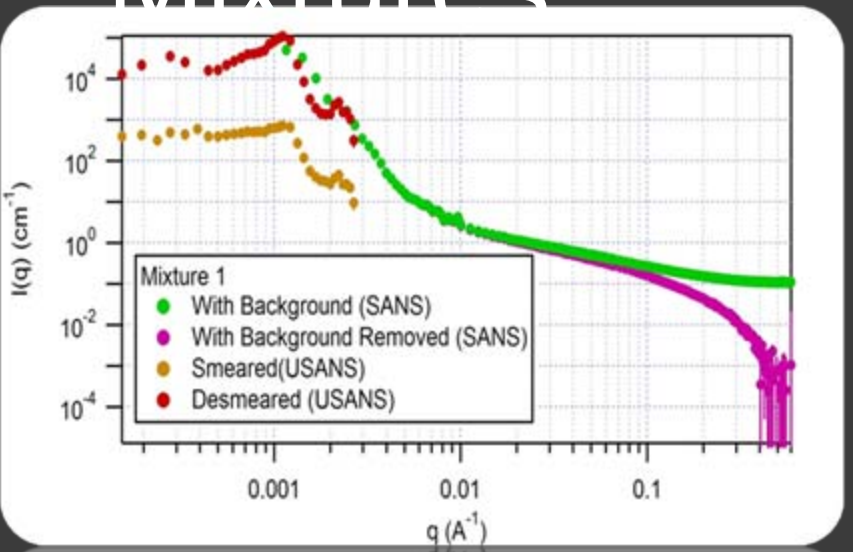
•Random Packing of Hard Spheres: ϕ=0.63
•Hexagonal Close Packing: ϕ=0.74

Last week… con’t

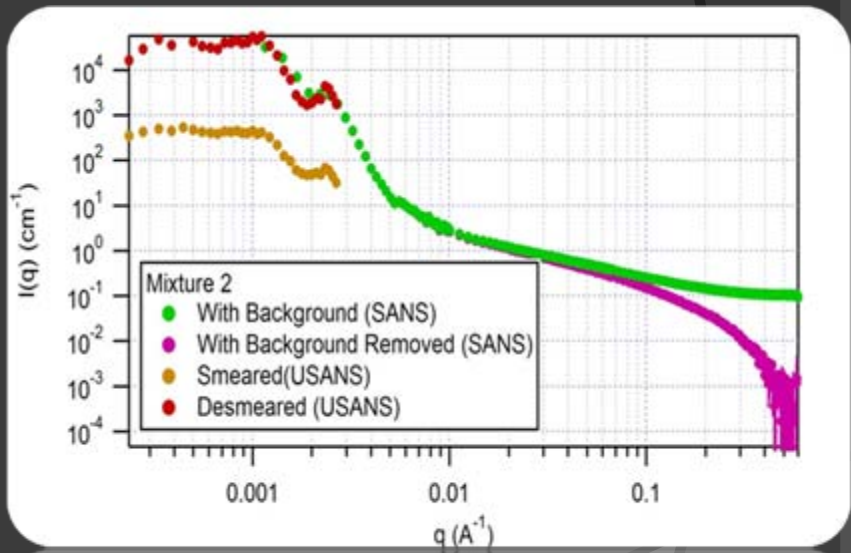
- SANS and USANS
  - Below LCST
- Low-high-low temperature cycle
  - Crystallization
  - Shows no difference in SANS, only visually



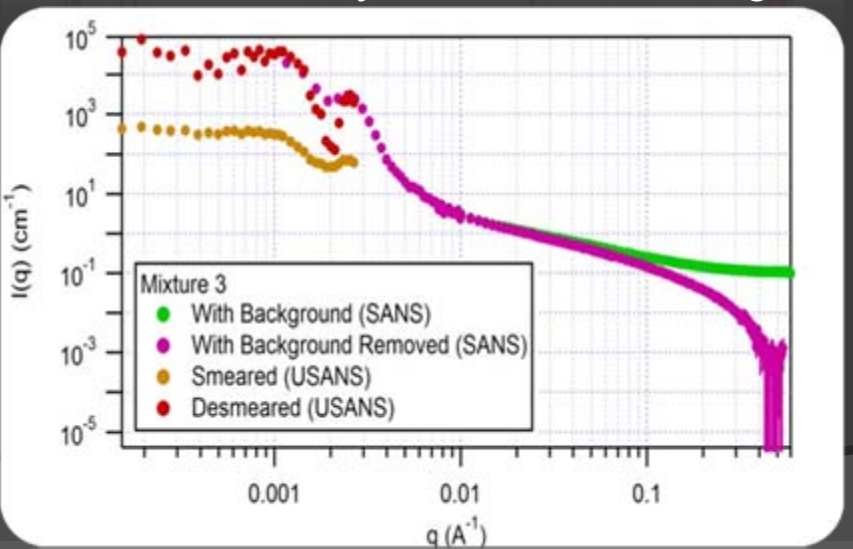
Concentrated Bimodal Mixtures



Mixture 1: 90% large/10% small
By Volume: 63% large, 7% small



Mixture 2: 70% large/30% small
By Volume: 49% large, 21% small



Mixture 3: 50% large/50% small
By Volume: 35% large, 35% small

Conclusion

- More small particles give less organized order
- Small particles are easy to make, but need detail cleaning
- Large particles are more difficult
- Temperature cycling increases order

Future Plans

- Develop “cleaning” process to rid sample of low molecular weight contaminants
- Model individual particle and mixtures
- Synthesize larger particles

Acknowledgements

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