Binary Colloidal Alloy Test (BCAT)

The Binary Colloidal Alloy Test (BCAT) hardware supports four experiments. The first hardware, BCAT-3, consisted of three separate investigations, Binary Alloy (BCAT-3-BA), Critical Point (BCAT-3-CP) and Surface Crystallization (BCAT-3-SC), which were delivered to the International Space Station (ISS) during expedition 8. The next hardware, BCAT-4, consists of two separate investigations, Critical Point (BCAT-3-4-CP, a continuation of the investigation on BCAT-3) and Polydispersion (BCAT-4-Poly).

Binary Colloidal Alloy Test-3 (BCAT-3)

The Binary Colloidal Alloy Test-3 (BCAT-3) hardware supported three investigations in which ISS crews photographed samples of colloidal particles (tiny nanoscale spheres suspended in liquid) to document liquid/gas phase changes, growth of binary crystals, and the formation of colloidal crystals confined to a surface. Colloids are small enough that in a microgravity environment without sedimentation and convection, they behave much as atoms and so can be used to model all sorts of phenomena because their size, shape, and interactions can be controlled.

The BCAT-3 payload consists of ten small samples of colloid alloys in which the microscopic colloid particles are mixed together into a liquid. These ten samples are contained within a small case that is the size of a school textbook. At the start of an experiment run, all ten samples are shaken to completely remix the colloid samples, much in the same way that salad dressing must be shaken to remix oil and vinegar. After the samples are mixed, what remains is periodically photographed using a digital camera until the colloid and liquid components of those samples have separated or the polymers have formed crystals. The samples can be remixed to repeat the experiment.

The ten samples in BCAT-3 were selected as part of three separate experiments examining different physical processes: critical point, binary alloys, and surface crystallization. Sample 7 makes up the BCAT-3-BA part of the experiment and it is a binary alloy.

Colloids are also technologically interesting because they are the right size to manipulate light. Natural opal is likely the oldest and best known of the “photonic” crystals that direct light. Shine white light on the opal and a rainbow appears, demonstrating how colors of light are split up and sent in different directions. The ability to better control the movement of light is a major technological goal, not only to build computers operating on light instead of electricity but also to harness the full capabilities of existing fiber-optic networks for improving communications. Crystal structures built from only one building block, e.g., the arrangement of colloidal silica spheres in an opal, are well understood, but their optical properties are limited. More useful photonic crystals can be built from two different types of building blocks mixed together, yielding a binary alloy. The resulting structures and their optical properties are vast, as both the size and the proportion of the two building blocks can be varied. How crystallization is affected by these changes is only beginning to be explored. Theoretical studies suggest that desired optical properties require more complicated crystal structures, but this has not been well explored experimentally. Microgravity is crucial to the binary crystal experiments, allowing the growth of crystals far larger than those created on the surface of Earth. The BCAT-3 binary alloy sample furthers previous investigations on binary growth in space.

Binary Colloidal Alloy Test – 3: Critical Point (BCAT-3-CP)

- Binary Colloidal Alloy Test – 3 and 4: Critical Point (BCAT-3-4-CP) uses microscopic spheres (described as colloids) suspended in a liquid to serve as a large-scale representation of the atoms and small molecules which constitute typical solids, liquids, and gases so that scientists can visualize what happens at the individual particle level when materials transition from liquids to gases.
- These systems of microscopic spheres help scientists visualize when specific conditions (i.e. temperature, pressure, and concentration) drive the formation of solids, liquids, and gases in smaller systems based upon atoms and simple, small molecules.
- Depending on their relative distances and energies with respect one another, atoms and molecules organize themselves to form gases, liquids, or solids. By varying the concentrations of the microscale spheres, this experiment studies the critical point of these systems where gases and liquids no longer exist as separate entities and a new state of matter forms when one reaches a critical point.
- BCAT-3-4-CP can only be performed in microgravity where gravitational forces do not interfere with the experiment.
- The application of this experiment in the near term is to enhance the shelf life of everyday products and in the longer term, the development of revolutionary materials for electronics and medicine.

Binary Colloidal Alloy Test – 3: Binary Alloys (BCAT-3-BA)

- The BCAT-3-BA develops new crystals from microscopic particles (known as colloids) that are capable of manipulating beams of light in a controlled and predictable way.
- Colloids are suspensions of very small particles within a liquid (paint, ink and milk) and can be used to study the solidification processes that may lead to colloid engineering and the manufacture of uniquely fine controlled materials from colloids. Colloids are easier to study in microgravity where the effects of sedimentation and convection are minimized.
- These new colloid materials have applications in the communications and computer industries for switches, displays and optical devices.

Binary Colloidal Alloy Test – 3: Surface Crystallization (BCAT-3-SC)

- The primary goal of Binary Colloidal Alloy Test – 3: Surface Crystallization (BCAT-3-SC) is to explore the patterns made by the natural ordering of liquid-suspended microscopic spheres in microgravity.

- Colloids are microscopic spheres suspended in a liquid. These microscopic spheres are suspended in a liquid containing an added polymer (a large synthetic molecule) which allows the scientists to control how the spheres come together. Under the right circumstances the presence of the polymer will cause these suspended spheres will prefer to crystallize on the container surfaces, rather than in the sample volume.
- Controlling the positioning of these micron sized spheres (or colloids) may be led to the development of next generation optical devices.

Binodal Colloidal Aggregation Test-4 (BCAT-4)

The Binodal Colloidal Aggregation Test (BCAT) hardware supports four experiments. The first hardware, Binary Colloidal Alloy Test – 3, consisted of three separate investigations, Binary Alloy (BCAT-3-BA), Critical Point (BCAT-3-4-CP) and Surface Crystallization (BCAT-3-SC), which were delivered to the International Space Station (ISS) during expedition 8. The next hardware, BCAT-4, consists of two separate investigations, Critical Point (a continuation of the investigation on BCAT-3) and Polydispersion (BCAT-4-Poly).

Binary Colloidal Alloy Test – 4: Critical Point (BCAT-4-CP)

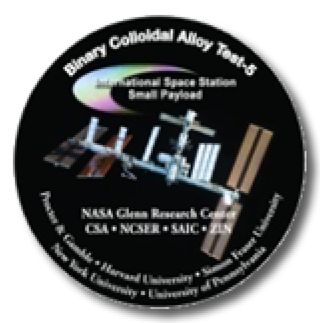
- Binary Colloidal Alloy Test – 3 and 4: Critical Point (BCAT-3-4-CP) uses microscopic spheres (described as colloids) suspended in a liquid to serve as a large-scale representation of the atoms and small molecules which constitute typical solids, liquids, and gases so that scientists can visualize what happens at the individual particle level when materials transition from liquids to gases.
- These systems of microscopic spheres help scientists visualize when specific conditions (i.e. temperature, pressure, and concentration) drive the formation of solids, liquids, and gases in smaller systems based upon atoms and simple, small molecules.
- Depending on their relative distances and energies with respect one another, atoms and molecules organize themselves to form gases, liquids, or solids. By varying the concentrations of the microscale spheres, this experiment studies the critical point of these systems where gases and liquids no longer exist as separate entities and a new state of matter forms when one reaches a critical point.
- BCAT-3-4-CP can only be performed in microgravity where gravitational forces do not interfere with the experiment.
- The application of this experiment in the near term is to enhance the shelf life of everyday products and in the longer term, the development of revolutionary materials for electronics and medicine.

Binodal Colloidal Aggregation Test – 4: Polydispersion (BCAT-4-Poly)

- Binodal Colloidal Aggregation Test – 4: Polydispersion (BCAT-4-Poly) consists of microscopic spherical particles (known as colloids) of a variety of different diameters (with the same average size) suspended in a liquid.
- The effects of this diversity in diameter among the particles will be studied with respect its effects on crystallization.
- Crewmembers photograph the samples over time to document the way that the particles crystallize in microgravity.
- Results from these experiments help scientists develop fundamental physics concepts which will enable the development of a wide range of new next generation technologies (such as in high-speed computers and advanced optical devices).

The BCAT-4-Poly polydispersed (characterizing the variation in particle size in the dispersed phase) and seeded samples consist of polymethyl methacrylate (PMMA) particles in an index matching decalin/tetralin mixture (the same colloid and solvent materials as the critical-point samples, but at a volume fraction of ~0.59). Although these samples are at or above the so-called glass transition point, colloidal crystals are expected to form. The particle size distribution and the addition of spherical seed particles should affect the free energy barrier for crystal nucleation, that is, the rate at which crystals nucleate. Photography will be used to study their evolution, with the hope of seeing white light backlit samples diffract the light so that the color changes with viewing angle. This will help reveal the shape of the nuclei, which provide information about the way the crystals grow in microgravity. The crystallites might grow fast in certain crystallographic directions which could give them a layer like structure. Also, their shape will give some hints about the processes that limit the growth. Comparison with analogous ground-based experiments will reveal differences in the growth behavior in microgravity.

Binary Colloidal Alloy Test – 5 (BCAT-5)



The Binary Colloidal Alloy Test – 5 (BCAT-5) hardware supports four investigations. Samples 1 – 5, the Binary Colloidal Alloy Test – 5: Phase Separation (BCAT-5-PhaseSep) will study collapse (phase separation rates that impact product shelf-life). In microgravity the physics of collapse is not masked by being reduced to a simple top and bottom phase as it is on Earth. Samples 6 – 8, Binary Colloidal Alloy Test – 5: Compete (BCAT-5-Compete) will study the competition between phase separation and crystallization, which is important in the manufacture of plastics and other materials. Sample 9, Binary Colloidal Alloy Test – 5: Seeded Growth (BCAT-5-SeededGrowth) will study the properties of concentrated systems of small particles when 99.8% are identical 0.36 diameter micron spheres and 0.2% are 4.14 microns in diameter (11.5x larger); these seed particles may cause heterogeneous crystal growth. Sample 10, Binary Colloidal Alloy Test – 5: Three-Dimensional Melt (BCAT-5-3D-Melt) will look at the mechanisms of crystal formation and 3-dimensional melting using colloidal particles that change size with temperature.

Binary Colloidal Alloy Test – 5: Three-Dimensional Melt (BCAT-5-3D-Melt)

The BCAT-5-3D-Melt sample will consist of a monodisperse nearly-hard-sphere colloidal suspension near its crystallization point. For this investigation small temperature changes that change the particle volume fraction will move the equilibrium system towards and away from the melting transition. The key ingredient in these samples is a thermosensitive polymer, poly (N-isopropylacrylamide (NIPA); the temperature-sensitive character of the samples stems from the temperature dependent solubility of NIPA polymer in water. Below its theta temperature (the temperature at which the coiled polymer molecules expand to their full contour lengths and become rod-shaped) of approximately 31 degrees C, water is a good solvent and NIPA polymer assumes a swollen coil form; in this regime a small increase of temperature increases monomer-monomer attractions and thus the size of the isolated polymer decreases. Above the theta temperature, water is a poor solvent, and NIPA has a collapsed globule form.

The BCAT-5-3D-Melt experiment will simply record sample temperature and observe (by photography) whether the sample crystallizes, noting at what temperature the sample experiences the fluid-solid transition. This information will also be useful for future experiments planned for ISS.

Binary Colloidal Alloy Test-5: Phase Separation (BCAT-5-PhaseSep)

BCAT-5-PhaseSep is a follow-on experiment to BCAT-3, which has been performed on several ISS increments, since increment 8, and BCAT-4, which was begun during Increment 17. Fabric enhancers are composed of mixtures of vesicle and polymers which, in some cases, form weak particle gels. These gels often coarsen exhibiting sintering, cracking or collapse, which significantly reduce the product shelf life. The factors that contribute to coarsening are enigmatic, as the processes are often concealed by the gravitational compression of the gel. Microgravity experiments offer a unique opportunity to elucidate coarsening mechanisms in these weak gel systems.

Binary Colloidal Alloy Test – 5: Compete (BCAT-5-Compete)

The BCAT-5-Compete samples consist of colloids suspended in solvent with added polymer. The polymer allows scientists to adjust the particle interactions though depletion attraction (for example, if the polymers are pushing on all sides of the colloidal particles in solution and two particles touch or one comes close to a wall, the polymers are no longer pushing on all sides, and this models attraction). By changing the amount of colloid and the relative amount of colloid and polymer, the equilibrium state of the sample can be changed. The BCAT-5-Compete samples will have equilibrium concentrations that result in mixtures of colloid-liquids, colloidal gas, and colloidal crystal. The purpose of these experiments is to study the kinetics that lead to these unique solutions.

The samples will be mixed (thoroughly randomized) and are expected to take several days to reach a nearly equilibrium state. During this time the EarthKAM system will be used to take high-resolution photographs of the samples at regular intervals. As the phase separation/crystallization kinetics begins immediately after the samples are mixed, the interval between images should be relatively short. As the kinetics proceed, the time between images can be increased. Imaging such as this has been performed during BCAT-3 and BCAT-4. The downlinked images will be analyzed using standard techniques to measure the spatial size of concentration variations in the sample or sizes of crystallites as a function of time.

Because crystals may be present, the BCAT-5-Compete samples will likely require that a small flashlight be used to determine optimal lighting and camera position. Once this is determined, the experiment can proceed using the EarthKAM software to control the camera to make a movie of the crystal formation process in an effort to record information about the time dependence of crystal formation.

Ultimately, the experiment is designed to determine if in samples that both phase separate and crystallize, if the dynamics of either process is affected by the other. For example, one possible scenario might be that phase separation, which induces local density increases, reduces the crystallite initiation time because of the increased density. These systems are relatively unexamined, and a wealth of new phenomena may be observed.

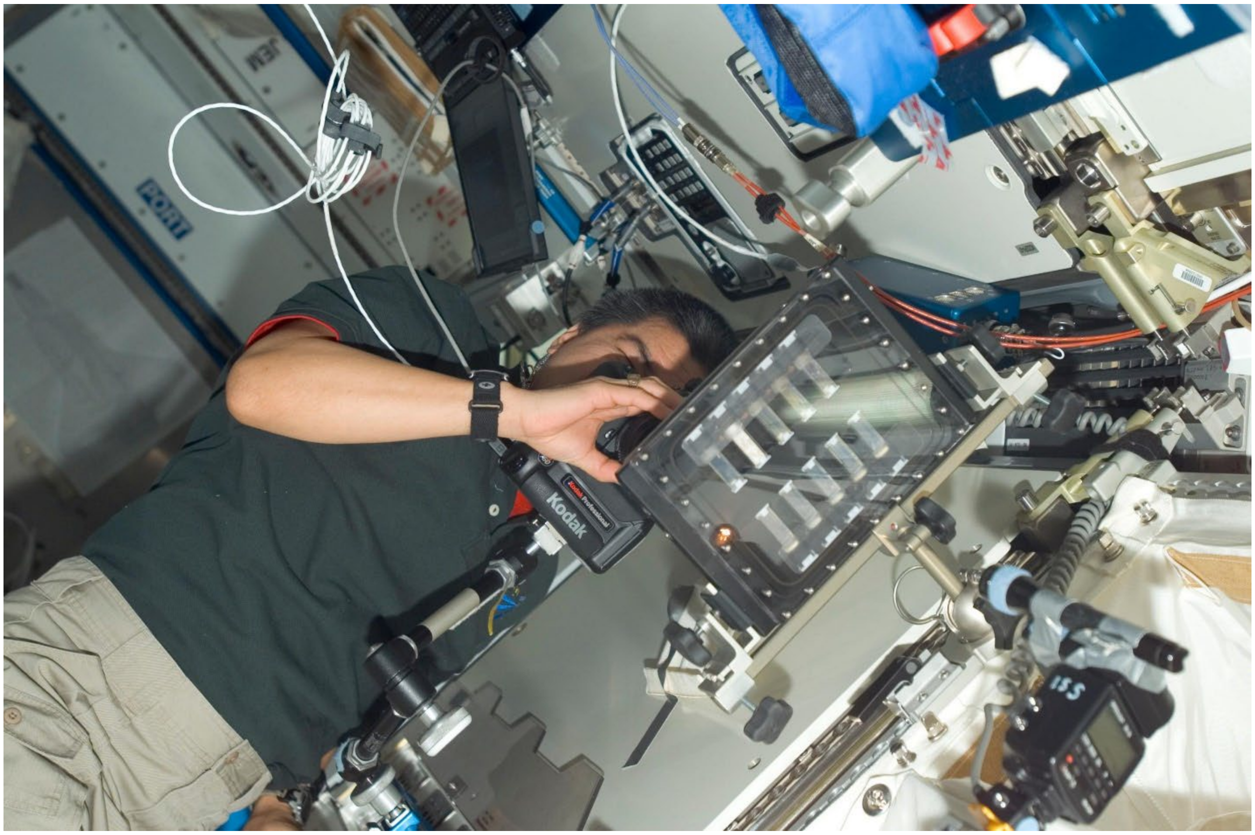
Binary Colloidal Alloy Test – 5: Seeded Growth

For the Seeded Growth Sample (9), plans are to experimentally explore the theoretical prediction that the use of seed particles can be used as a way to control the size of crystallites. The control of crystallite size is important in many industrial processes. By introducing the right size and concentration of 'nano-dirt', we use this experiment to record the effect of large (11.5X) spherical seed particles on crystallization. Small nuclei grow on the seed and as they grow, the presence of a larger curved substrate makes it difficult to maintain an unstrained structure. At some stage, the precritical nuclei break away from the surface, and the critical nucleus is only formed in the bulk. The seed particles are identical to the smaller PMMA spheres, including the thin polymeric steric layer attached to the particle surfaces.

Binary Colloidal Alloy Test-6 (BCAT-6)

The Binary Colloidal Alloy Test-6, Phase Separation (BCAT-6), Phase Separation) experiments examine conditions that result in colloidal crystallization, melting, self-organization, and phase separation of colloidal systems. The evolution toward equilibrium through time is captured on the International Space Station (ISS) or with the accurate measurement of time frames correlated to the pictures taken by a new kind of automated camera.

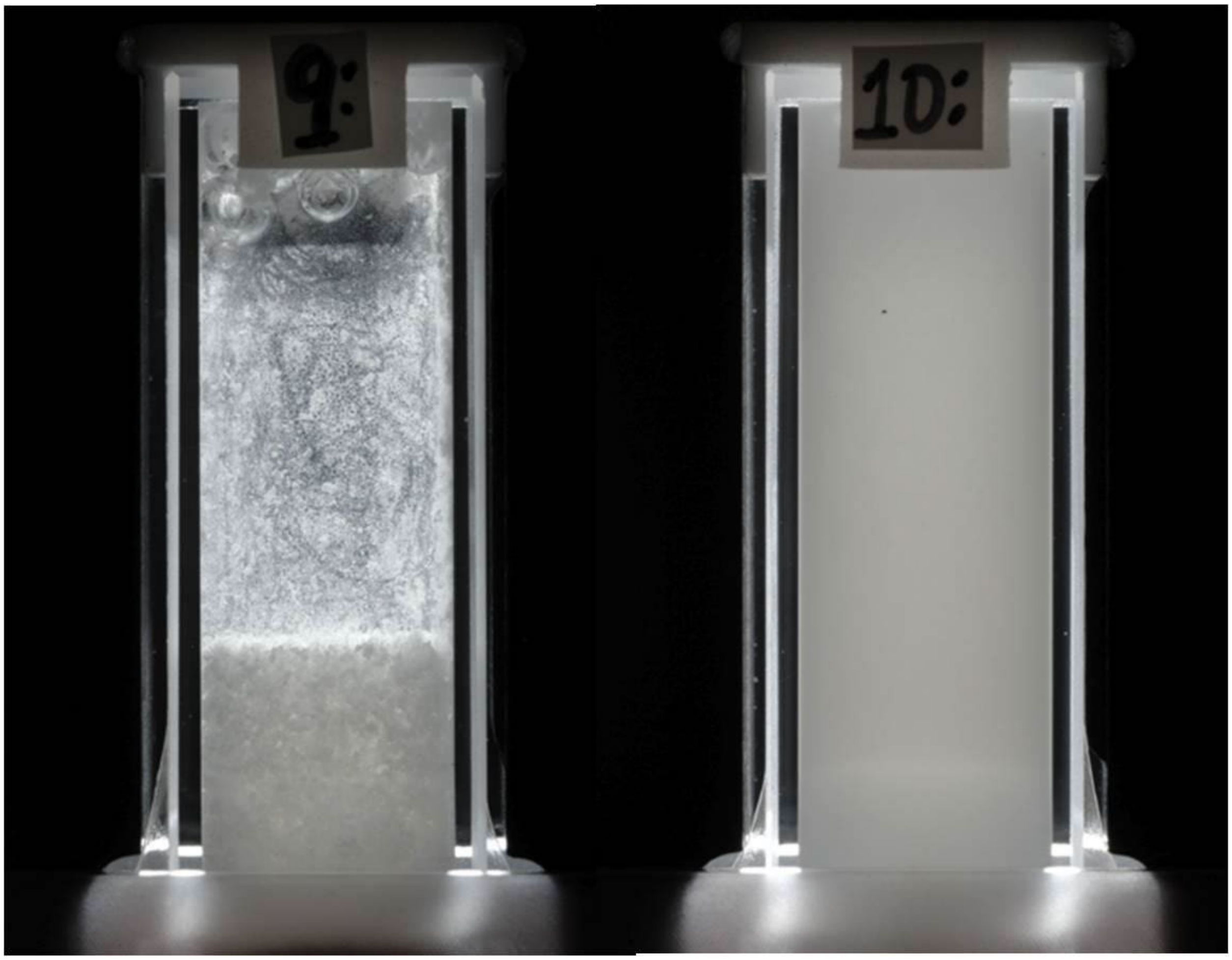
Binary Colloidal Alloy Test – 6 – Phase Separation (BCAT-6, Phase Separation)



The Binary Colloidal Alloy Test-6, Phase Separation (BCAT-6, Phase Separation) experiments examine conditions that result in colloidal crystallization, melting, self-organization, and phase separation of colloidal systems. The evolution toward equilibrium through time is captured on the International Space Station (ISS) or with the accurate measurement of time frames correlated to the pictures taken by a new kind of automated camera.

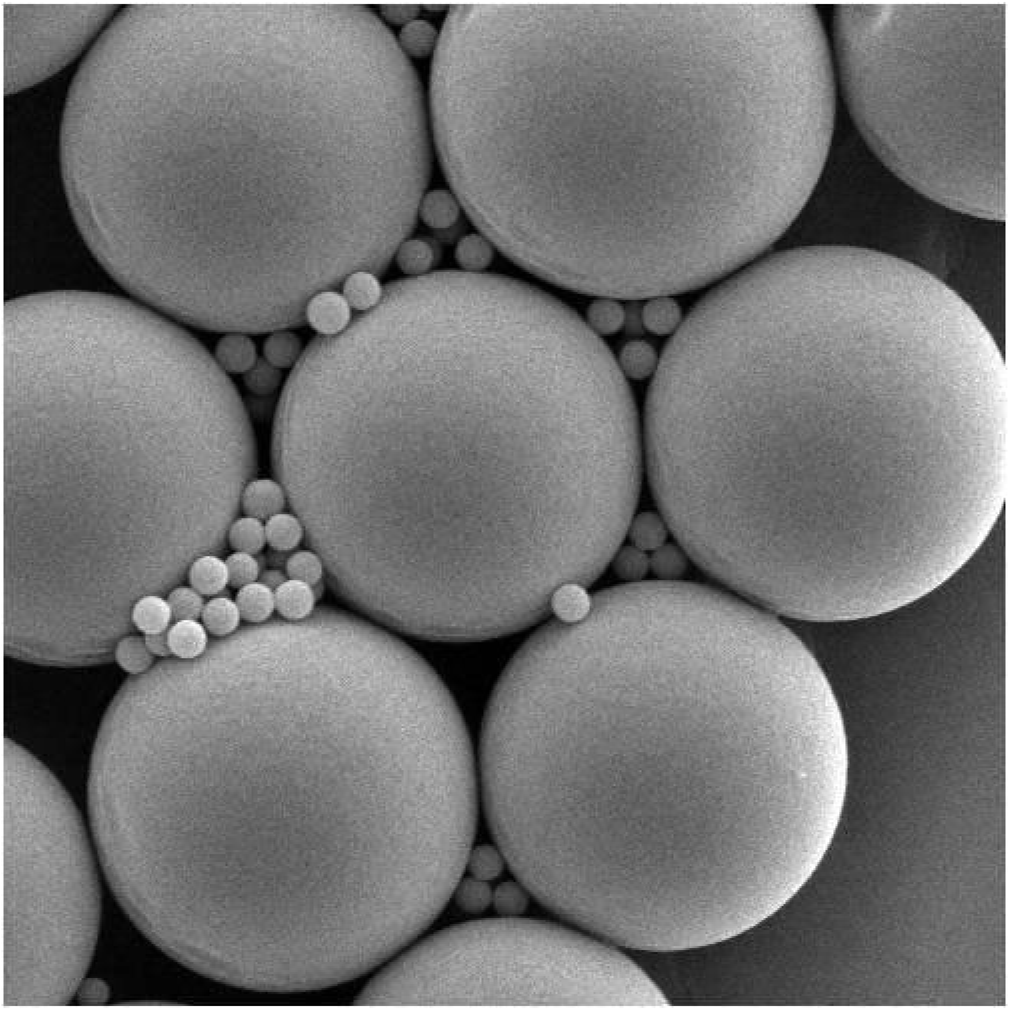
There are three principal objectives associated with the phase separation studies in BCAT-6, Phase Separation. The first objective is to measure phase separation rates in microgravity in order to develop the underlying theory for predicting product shelf life. The second is to understand how to control the colloidal forces between particles to determine the physics underlying the phase separation process that forces the placement of additives in products to extend their shelf life. It is for this reason, among others, that finding the critical point is so important. The critical point is the point at which gas transitions into a liquid or supercritical fluid. A supercritical fluid has the properties of both a gas and a liquid. The final objective is to understand the fundamental properties of colloid-polymer mixtures to further improve the commercial utilization of these systems. The fundamental fluid physics research could provide the understanding needed to enable the development of better, less expensive, longer shelf-life household products, foods, and medicines. Stabilizers in these products are expensive, take up volume, and are needed to extend the life of products.

Binary Colloidal Alloy Test 6: Colloidal Disks (BCAT-6-Colloidal Disks)



The Binary Colloidal Alloy Test 6: Colloidal Disks (BCAT-6-Colloidal Disks) experiments use liquids containing microscopic, suspended particles, known as colloids, as models for studying liquid crystals. The use of unevenly shaped particles clumped together into colloidal disks should produce a new phase, which has been predicted but never before seen. It is important to fully understand the properties of liquid crystals since they are widely used in televisions, computers, cell phones and much more.

Binary Colloid Alloy Test-6: Seeded Growth (BCAT-6-Seeded Growth)



The Binary Colloid Alloy Test-6: Seeded Growth (BCAT-6-Seeded Growth) builds on previous research looking at how dense groups of particles may be coaxed to form crystal structures when much larger "seed" particles are added. Some materials may consist of large individual crystals, or groups of many smaller crystals organized in a larger structure. Knowing when and how either type of crystal will form gives insight into how to control crystal growth which is important in many industrial processes.

Binary Colloidal Alloy Test 6: Polystyrene – Deoxyribonucleic Acid (BCAT-6-PS-DNA)

The Binary Colloidal Alloy Test 6: Polystyrene – Deoxyribonucleic Acid (BCAT-6-PS-DNA) uses DNA as a type of molecular glue to specifically stick small particles together. The experiment uses microscopic polymer beads in solution (colloids) that have been coated with DNA. The DNA only binds to its complement and hence keeps specific particles together to form designer crystals.