GENETICALLY ENGINEERED MATERIALS
SCIENCE & ENGINEERING CENTER

NSF-MRSEC at the University of Washington

Student Worksheet

Order from Disorder – A Macroscale Simulation to Illustrate a Nanoscale Phenomena

In the macroscopic world objects can be manipulated fairly easily to construct larger objects. Buildings being made of concrete and steel subunits, cars made from various metal, plastic and rubber parts and just two examples of ordered arrangements of smaller elements in a macroscopic world. How do smaller elements such as atoms, molecules, proteins, etc., become structures than can in turn be used to make the macroscale items that we utilize on a daily basis?

One of the goals of Nanotechnology is to discover mechanisms that are used to form organized groups of materials that can in turn be used to make larger objects. Knowing how the organization occurs, how the structure is formed, can lead to ways to improve the structure, create a more consistent material or utilize the material in a more effective manner. How are these ordered structures formed? What factors influence the formation of a consistent pattern of organization? As technology advances we require materials with much more sophisticated architectures. Traditional heat and beat treatments have size limitations which restrict our ability to make the technology that we need. Thus, self-assembly utilizes the forces seen used by Mother Nature to build things from small to large.

By the very nature of Nanotechnology, the elements that we work with are very small, too small to be manipulated by any mechanical movement on our part, or if they can be manipulated by our actions, the time and energy required is prohibitive. Therefore, these ordered patterns in a material need to be able to generate themselves on their own. How does this occur? How do a random assortment of particles become the ordered arrangement that ultimately constitutes a piece of metal, plastic, glass, etc. that we can use to make a piece of equipment? Is there a way to simulate the formation of an ordered arrangement of atoms into an organized structure with minimal energy applied on our part?

In this experiment, we will focus on using small Styrofoam pieces to simulate much smaller things like proteins, molecules and nano-scale building blocks to create a mechanism for illustrating self-assembly. By attaching small magnets to every other edge of the flat Styrofoam, we can create an attractive force that would simulate forces between atoms or molecules as a result of electrostatic forces between very small

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particles. These attractive forces are then used to draw individual elements into an ordered structure.

Materials

- Flat sheet of Styrofoam, ~0.25"
- Small polar neodymium rare earth magnets
- Glass pan or tray with a flat, clear bottom approximately 15 cm diameter and a few inches high
- Cutting template
- Water
- Scissors
- Razor blades Blank white paper
- Ruler, protractor

Safety equipment: Use extreme caution when cutting with a razor blade. Always hold blade opposite the sharp edge.

Experimental Procedure

1. Make a prediction regarding the type of ordered pattern that might develop from a group of hexagon patterns with magnets placed on alternating edges – placed in water and allowed to order themselves.
2. Make a sketch of this ordered pattern in your lab book.
3. Observe the teacher's demonstrations on the overhead projector.
4. Record the initial appearance of the hexagonal arrangement.
5. As he/she gently moves the pan back and forth to cause movement of the hexagonal shapes, observe the assembly process
6. Make another sketch of the hexagonal arrangement after the shapes have had time to order themselves.
7. Choose a letter in the alphabet such as O or T that is relatively simple in design.
8. Determine what type of shape or shapes could be constructed such that when magnets are applied, these structures would form into the shape of the letter. The

final letter should be composed of at least 4 separate shapes, similar in size that will combine to form the final letter shape.

9. Using paper, ruler and protractor, cut out paper shapes as determined in step #8. Indicate on each paper shape areas of attractive force – potential attachment points for a magnet.
10. Paste the paper shapes to data page in notebook, being sure to match up areas identified as having attractive force behavior.
11. Build the basic shapes identified in step #8
12. Attach magnets to shapes in an arrangement that might best encourage the appropriate organization into the desired letter.
13. Place completed Styrofoam pieces in the pan of water and move the pan to move pieces so that self assembly of letter proceeds.
14. After significant time of movement (1 to 2 minutes), make a sketch of the final pattern.

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Data and Observation:

Sketch of predicted pattern from using hexagons:	
Sketch of initial appearance of hexagons in pan:	
Sketch of final ordered arrangement of hexagons in pan:	

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Sketch of paper piece showing location of attractive force (magnet placement)	
Sketch of initial appearance of shapes for letter – in pan:	
Sketch the final arrangement of shapes for letter – in pan	

Conclusion: Write a paragraph describing the effect of your agitation of the hexagonal spheres. Describe the type of movement that produced the most ordered result.

Summary Questions:

1. What ordered pattern did you predict would form from the hexagon shapes?
2. What type of movement of the pan was most effective in obtaining an ordered pattern using the hexagon shapes? What is your evidence to support this?

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3. If the hexagon shapes were individual molecules or proteins, what do the magnets represent?
4. What regions of each shape represent a hydrophilic attraction?
5. What regions of each shape represent a hydrophobic attraction?
6. What basic shape was used to form a letter? Was more than one shape used? Explain why you chose the shape(s).
7. What letter did you choose to form? Describe how effective you were in forming the letter using the basic shapes you constructed.