NEATEC Learning Module

Northeast Advanced Technological Education Center

Chemistry of Hydrophobic Sand

Secondary Level - Grades 9th-10th – Assessment

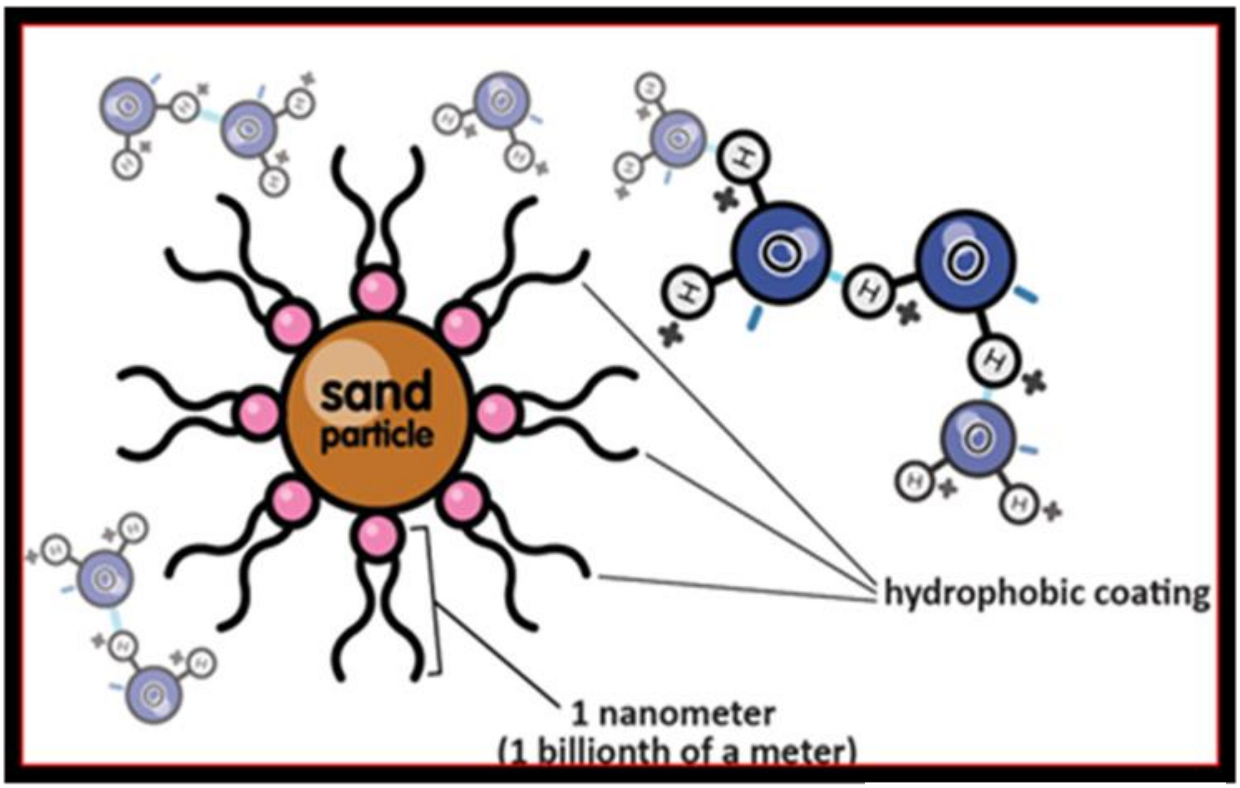

Image credit: NanoDays

Northeast Technological Education Center (NEATEC)
Hudson Valley Community College

STEM Introduction Topic

Chemistry of Hydrophobic Sand

Secondary Level - Grades 9^{th}-10^{th} – Assessment

NEATEC Mission Statement:

"The Northeast Advanced Technological Education Center (NEATEC) is a Regional Center for Semiconductor and Nanotechnology Education funded by the National Science Foundation (NSF DUE #1003574) to serve as a critical, sustainable resource to create and maintain a skilled technical workforce for the semiconductor and nanotechnology industries in New York State and Western New England. Through an extensive network of community college, university, and industry partners, NEATEC will identify the essential technician competencies and skills required by such a workforce. NEATEC will develop curricular components and delivery methods to impart those skills to students. NEATEC will also create and disseminate educational materials to support curricula implementation at its community college and high school partners and provide professional development activities for K-12 schools and community college faculty. Lastly, through partner internships, co-ops, shadowing opportunities and outreach activities, NEATEC will educate current and future students regarding technological career pathways and expand the pipeline of K-12 students interested in semiconductor and nanotechnology career options."

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What is STEM?

With all the acronyms that determine hundreds of different areas of education, it is easy to confuse them all. Since 2001, the letters STEM have been a normal part of educational vocabulary.

The acronym STEM stands for Science, Technology, Engineering, and Mathematics. This program was started by Judith A. Ramaley, the former director of the National Science Foundation's education and human-resources division. This approach to education is designed to revolutionize the teaching of subject areas such as mathematics and science by incorporating technology and engineering into regular curriculum by creating a "meta-discipline."

There is more; STEM Education attempts to transform the typical teacher-centered classroom by encouraging a curriculum that is driven by problem-solving, discovery, exploratory learning, and requires students to actively engage a situation in order to find its solution.

Science, technology, engineering and mathematics (STEM) education often has been called a meta-discipline, the "creation of a discipline based on the integration of other disciplinary knowledge into a new 'whole'. This interdisciplinary bridging among discrete disciplines is now treated as an entity, known as STEM (Morrison, 2006). " STEM education offers students one of the best opportunities to make sense of the world holistically, rather than in bits and pieces. STEM education removes the traditional barriers erected between the four disciplines, by integrating them into one cohesive teaching and learning paradigm. Morrison and others have referred to STEM as being an interdisciplinary approach. "STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (Tsupros, 2009)."

What is a NEATEC Learning Module (NLM)?

A NEATEC Learning Module (NLM) is self-contained unit that can be incorporated into existing science, math, and technology classes to supplement and enhance the content and the laboratory activities of the class. Each module includes all or some of the following sections:

- Background information about the topic of the unit
- A teacher's guide
- A student's guide
- List of lab materials for laboratory activities
- A list of teacher's and student's resources
- Power Point slides

The set of modules offered by NEATEC are divided into five categories based on the level of understanding of the participants:

1. NLM K-2: These are units suitable for students in grades Kindergarten to 2nd grades.
2. NLM 3-5. These are units suitable for students in grades 3rd to 5th grades.
3. NLM 6-8. These are units suitable for students in grades 6th to 8th grades.
4. NLM 9-12. These are units suitable for students in grades 9rd to 12th grades.
5. NLM for Community Colleges.

NEATEC Learning Modules include topics on Nanotechnology, Semiconductors, Photovoltaic, Alternate Energy, Mathematics, General Science and Technology.

Grade Level: High School Level - Grades 9-10

Essential Questions:

- How does Magic Sand© work?
- What is the “Lotus Effect” and what does it have to do with chemistry?
- How is nanoscience related to Magic Sand©?
- How has knowledge of this been used to improve our lives?

Objective(s):

- Activity 1: Students will make their own “magic” sand by coating regular beach sand particles with silicone spray to make them hydrophobic.
- Activity 2: Students will investigate the interaction of normal beach sand and hydrophobic Magic Sand© with water by comparing how they differ when water is added to sand and when sand is added to water and observing their hydrophobicity.
- Activity 3: Students will investigate properties of normal beach sand and Magic Sand© by adding sand to water and oil and understand how polarity plays a role.

New York State Common Core Learning Standards *(**To be updated**)***:**

Mathematics Standards:

- HS.N-Q.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- HS.N-Q.2 Define appropriate quantities for the purpose of descriptive modeling.
- HS.N-Q.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

English Language Arts Standards

- RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
- RST.9-10.2 Determine the central ideas or conclusions of a text; trace the text’s explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
- RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
- RST.9-10.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 9–10 texts and topics*.
- RST.9-10.5 Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., *force, friction, reaction force, energy*).
- RST.9-10.6 Analyze the author’s purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address.
- RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

- RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.
- RST.9-10.9 Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

Learning Standard 1: Analysis, Inquiry and Design. *Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate to pose questions, seek answers, and develop solutions.*

- Scientific Inquiry Key Idea 1: The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.
- Scientific Inquiry Key Idea 2: Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.
- Engineering Design Key Idea 1: Engineering design is an iterative process involving modeling and optimization (finding the best solutions within given constraints); this process is used to develop technological solutions to problems within given constraints.

Learning Standard 4: The Physical Setting. *Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.*

- Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.
  - 3.1 Explain the properties of materials in terms of the arrangement and properties of the atom that compose them.
  - 3.1dd Compounds can be differentiated by their physical and chemical properties.
  - 3.1oo A solution is a homogeneous mixture of a solute dissolved in a solvent. The solubility of a solute in a given amount of solvent is dependent on the temperature, the pressure, and the chemical natures of the solute and solvent.

- Key Idea 5: Energy and matter interact through forces that result in changes in motion.
  - Explain chemical bonding in terms of the behavior of electrons
  - 5.2l Molecular polarity can be determined by the shape of the molecule and distribution of charge. Symmetric (nonpolar) molecules include CO_2, CH_4, and diatomic elements. Asymmetrical (polar) molecules include HCl, NH_3, and H_2O.
  - 5.2m Intermolecular forces created by the unequal distribution of charge result in varying degrees of attraction between molecules. Hydrogen bonding is an example of a strong intermolecular force.
  - 5.2n Physical properties of substances can be explained in terms of chemical bonds and intermolecular forces. These properties include conductivity, malleability, solubility, hardness, melting point, and boiling point.

Special Education Accommodations & Modifications:

- Experiments can be done as a whole group exploration rather than as individual small groups.

Materials:

Materials supplied in kit:

Activity 1: Making Hydrophobic Sand

- Normal Beach Sand
- Silicone Spray or Scotch Guard
- Baking Tray
- Aluminum Foil
- Newspaper
- 2 Cups or Beakers
- Spoon

Activity 2: Magic Sand© and Hydrophobic Effect

- Normal beach sand
- Magic sand ©
- 2-100ml beakers
- 500ml beaker
- 4 trays (about 15cm^2 x 3cm deep)
- Disposable pipette
- Spoon
- Paper towels
- Containers for collection of used sand

Activity 3: Exploring Properties of Normal Sand and Magic Sand©

- 500 mL of Mineral or vegetable oil
- 15 grams of normal beach sand
- 15 grams of Magic Sand©
- Mixing rod

Materials *NOT* supplied in kit:

Activity 1: Making Hydrophobic Sand

- Distilled Water
- Paper Towel

Activity 2: Magic Sand© and Hydrophobic Effect

- Distilled Water
- Paper Towel

Activity 3: Exploring Properties of Normal Sand and Magic Sand©

- Distilled Water
- Balance (can be shared)

Assessment:

Student completion of worksheet.

Ability to answer both pre and post activity questions at the conclusion of the module. Extension questions optional.

Chemistry of Hydrophobic Sand – Pre-Activity and Post-Activity Questions

Pre-Activity Questions:

1. In the first activity, you will make your own “magic” sand by coating normal beach sand with a hydrophobic substance. How can you test to see if you have successfully made hydrophobic sand?
2. Predict what will happen when you put a droplet of water on a pile of Magic Sand©. Explain.
3. Predict what will happen when you put normal beach sand and Magic Sand© in oil. Explain.

Lab & worksheet completion by students in groups of 2 is ideal; however groups of 3-4 would also work.

Post-Activity Questions:

1. Why did normal beach sand get wet in water while the Magic Sand© stayed dry?
2. What happened when you put droplets of water on a pile of Magic Sand©? Why?
3. Another use for Magic Sand© is for keeping household plants healthy. Can you think of how mixing some Magic Sand© in the soil can keep plants healthy?

Extensions:

1. Explain why water is a liquid and methane (CH_4) is a gas (at atmospheric pressure and room temperature).
2. Predict how normal beach sand and Magic Sand© would behave in methanol (CH_3OH). Explain.

Chemistry of Hydrophobic Sand – Resource Information for Instructor Proficiency
(links are active on pdf)

Background on Molecular Structure and Polarity

- http://www.chem.ufl.edu/~itl/2045/lectures/lec_16.html
- http://dwb4.unl.edu/Chem/CHEM869E/CHEM869ELinks/www.uis.edu/7Etrammell/organic/introduction/polarity.htm
- http://mysite.verizon.net/kdrews47/interactions/interactions.html

Background on Hydrogen Bonding

- http://www.elmhurst.edu/~chm/vchembook/161Ahydrogenbond.html
- http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/H/HydrogenBonds.html

Background on Hydrophobic Effect and Lotus Effect

- http://en.wikipedia.org/wiki/Hydrophobe
- http://en.wikipedia.org/wiki/Lotus_effect

Background and Applications of Magic Sand

- http://www.nisenet.org/sites/default/files/catalog/uploads/5400/prodsand_guide_15nov10_0.pdf
- http://www.retroland.com/magic-sand/

Magic Sand Activity from University of Wisconsin-Madison
http://education.mrsec.wisc.edu/documents/MagicSand_ProgramGuide.pdf

Magic Sand and the Hydrophobic Effect – Teacher's Guide from Center for Advanced Materials for Purification of Water with Systems
http://www.watercampws.uiuc.edu/waterclear/labs/lessons/magicsand_teacher_guide.pdf

The following 3 pages on background information are for Student Handouts to discuss with your class prior to Activity and Worksheet Completion.

Background Information:

Normal beach sand is polar, which makes it hydrophilic. When sand comes in contact with water, the polarity of the water causes it to become a type of glue that helps stick the sand together. Anyone who has tried to build a sand castle knows that wet sand holds shape much better than dry sand. In this module, students will consider the differences between the behavior of hydrophobic sand and beach sand in different solvents and come up with explanations for these occurrences based on knowledge of polarity, intermolecular bonding, and solubility. Hydrophobic sand, also known as Magic Sand©, is an example of science on the nanoscale. Treatment of the surface of individual grains of sand with a hydrophobic monolayer results in a new type of sand that behaves very differently from regular beach sand.

Nanotechnology has begun changing products that we use in everyday life, mostly through surface treatments. Many people are already aware of stain resistant Nano-Tex© fabric, which exhibits hydrophobic (water-repellant or, literally, "water-fearing") properties. This activity explores Magic Sand© which has similar hydrophobic properties as stain-resistant fabric. Hydrophobic sand, also known as Magic Sand ©, is an example of how nanoscale science can be used to understand drastic changes in a material's behavior or appearance at the macroscale. Treating the surface of individual grains of the sand makes a new type of sand that behaves very differently from regular beach sand.

To understand how hydrophobic sand works, one first must understand some basic principles of water. Water molecules are highly polar, which means that the molecules have slightly positively and slightly negatively charged ends. Polarity arises when the electrons in the molecule's bonds are not shared equally between the atoms, creating slightly positive or slightly negative charges on different atoms within the molecule. In water, the partial charges on the atoms are arranged uniquely in a bent structure, causing the molecule to have a positively charged end and a negatively charged end. The positively charged end of one water molecule strongly interacts with the negatively charged end of another molecule, much like how the poles of a magnet interact. These interactions, or intermolecular forces of attraction, are called "hydrogen bonds", and are directly responsible for some of water's unique properties (high boiling point, high surface tension, low freezing point, etc.).

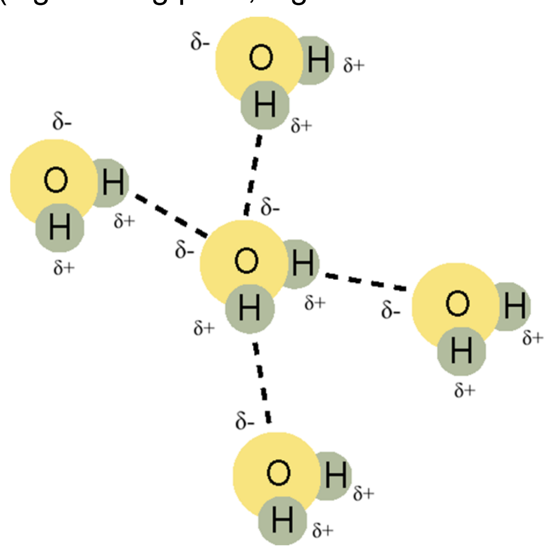


Figure 1: Hydrogen bonding between water molecules
(http://ed101.bu.edu/StudentDoc/Archives/spring04/srb2007/Site/Ice.%20Clouds.%20and%20Rain.htm)

The interactions between the water molecules are so strong that substances made up of non-polar molecules (which cannot form hydrogen bonds) cannot mix with water. Vegetable oil, for example, is made up of non-polar molecules. Non-polar molecules share electrons equally, and do not have positively charged and negatively charged ends in contrast with water. When the oil comes in contact with water it spreads across the water's surface, but does not mix with the water. Water either repels or completely envelops non-polar substances so it can continue to bond with itself. Hydrophobic, or water hating, molecules are always non-polar, and include greasy substances like oils, fats, or tar.

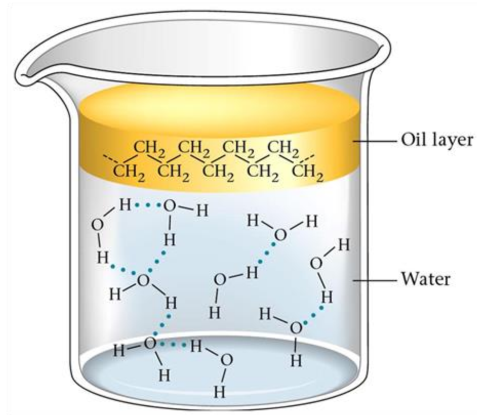


Figure 2: Water and oil don't mix. Left image shows oil and water in a cup and the right image shows an illustration on a molecular level.
(http://commons.wikimedia.org/wiki/File:Water_and_oil.jpg,
Zumdahl, Zumdahl, DeCoste, World of Chemistry 2002, page 470)

Another interesting example of water molecules interacting with a non-polar substance is water on lotus leaves. The lotus plant (*Nelumbo Nucifera*) is a native Asian plant with very hydrophobic or water repelling leaves. When droplets of water come in contact with a lotus leaf, water molecules cannot interact with the non-polar chemical groups of the leaf causing the water droplet to form a bead held by the strong intermolecular forces of water molecules. In other words, the water molecules prefer to stick to one another than to stick to the chemical groups on the surface of the leaf. This is called the *Lotus Effect*. When the water rolls off the lotus leaf, it drags dirt along with it cleaning the leaf. We say that the surface of the lotus leaf self-cleans.

Unlike oil or lotus leaves, natural sand is attracted to water. It is hydrophilic, or water loving. At the beach, natural sand's surface readily absorbs water when waves crash upon the shore. The atoms on the surface of natural sand particles have positive and negative charges. The charges on the surface of the sand are attracted to the positively and negatively charged ends of the water molecules. Therefore, the water and the sand are attracted to each other. One can easily see this when building a sand castle.

Using nanotechnology, scientists have created a way change the way sand and water interact. Natural sand grains are coated with a special silicon-based compound at the nanoscale. One end of the compound is hydrophilic—therefore it is attracted to the sand particle. However, the other end of the compound is hydrophobic, so it sticks out away from the grain of sand. This process creates a non-polar (hydrophobic) layer on the surface of the sand grain. The hydrophobic layer repels water from the surfaces of individual grains of sand.

Regular Beach Sand **Magic Sand**

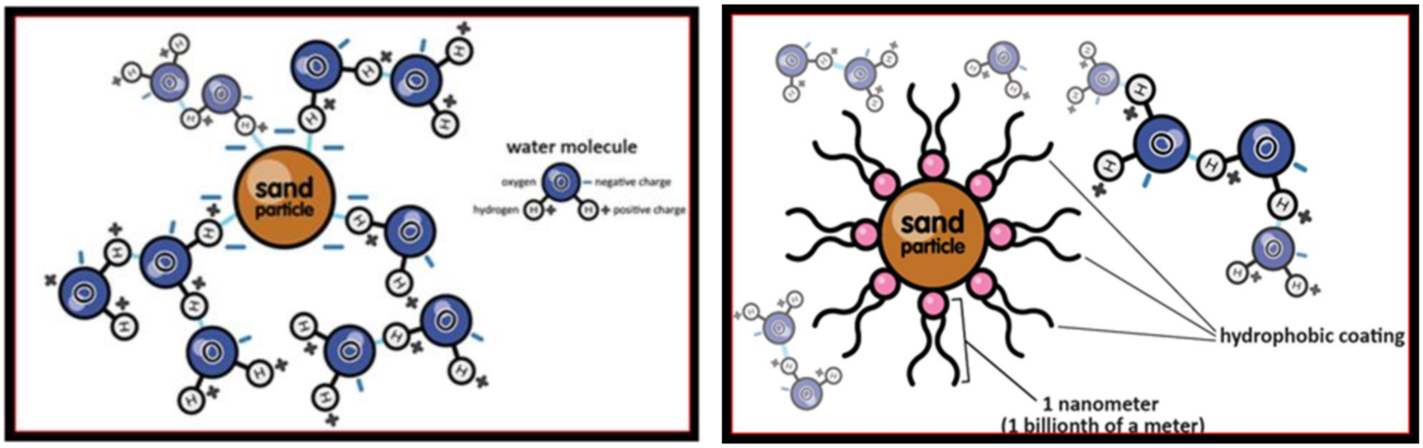


Figure 3: Interaction of water molecules with regular beach sand particles and magic sand particles which have a hydrophobic coating. (Images taken from NanoDays)

When Magic Sand© is sprinkled on the surface of water, the water molecules prefer to bond with other water molecules instead of with the Magic Sand©. This prevents the grains of magic sand from breaking through the surface. The magic sand then stays on the water's surface until enough sand accumulates to overcome the surface tension. This same effect keeps magic sand dry. Water molecules will not attach to individual grains of magic sand or flow between them. Other liquids, however, will soak into magic sand. For instance, oil's nonpolar nature allows magic sand to be attracted to it and thus allows magic sand to absorb large quantities of oil.

Application: Scientists have found ways to take advantage of the hydrophobic properties of materials such as Magic Sand ©. Magic Sand © was originally developed for use in cleaning up petroleum oil spills. The sand will bond with petroleum oil floating on the surface of water, eventually adding enough weight to make the mixture sink to the bottom. The petroleum oil could then be dredged up from the bottom of the body of water and removed for treatment. Unfortunately, this process requires large amounts of Magic Sand ©, making it too expensive for current use. Nevertheless, if the price of manufacturing Magic Sand ©decreases, its use for environmental cleanup could become more popular in the future.

Magic Sand© has also been used to protect electrical and telephone wires in extremely cold climates. The wires are buried underground for protection from the extreme temperatures. However, when the water in the ground freezes, repairs become difficult and labor-intensive because the layers of dirt covering the wires are very hard. To solve this problem, utility workers first cover the underground electrical junction boxes with a thick layer of Magic Sand. The hole containing the junction box is then capped with a thin layer of normal soil. When water from rain or melted snow seeps into the ground, the layers of Magic Sand repel the water and prevent it freezing around the junction box. If workers need to perform repairs on the junction box, they only need to remove the thin layer of frozen soil on top of the Magic Sand©. The thin layer is easy to break through. Workers can then easily remove the Magic Sand© and perform the necessary repairs.

Name________________________________ Period___________
Date__________________

Activity 1: Making Hydrophobic Sand

Overview: In this activity, we will be making our own “magic” sand by coating regular beach sand particles with silicone spray to make them hydrophobic.

Materials:

Normal Beach Sand
Silicone Spray or Scotch Guard
Baking Tray
Aluminum Foil
Newspaper
2 Cups or Beakers
Distilled Water
Spoon
Paper Towel

Experimental:

- ☐ Cover the baking tray with aluminum foil
- ☐ Lay a couple layers of newspaper and put the baking tray on it. Be sure to do this outside or in fume hood where you have good ventilation.
- ☐ Put a layer of beach sand on the baking tray. Make sure it’s an even layer.
- ☐ Take the silicone spray, and start spraying off the baking tray first and then spraying over the sand back and forth slowly covering the entire tray to get a good coating.
- ☐ Gently shake the tray to stir the sand and then spread the sand to get an even layer again.
- ☐ Repeat the last two steps 4 times.
- ☐ Allow the sand to sit overnight.

Record your observations:

- [ ] Test both the original sand and the hydrophobic sand you created by taking a handful and dunking it in water in a separate cup or beaker.
- [ ] Scoop some out with a spoon and spread it on a paper towel.

Record your observations:

Did you succeed in making hydrophobic sand? Why or Why not?

Explain how you applied nanotechnology in making hydrophobic sand. Be sure to include an illustration with labels!

How can you improve your process to make better hydrophobic sand?

Name___________________________________ Period____________
Date___________________

Activity 2: Magic Sand© and Hydrophobic Effect

Overview: In this activity, we will investigate the interaction of normal beach sand and hydrophobic Magic Sand© with water by comparing how they differ when water is added to sand and when sand is added to water and observing their hydrophobicity.

Materials:

Normal beach sand
Magic sand ©
2-100ml beakers
500ml beaker
4 trays (about 15cm^2 x 3cm deep)
Disposable pipette
Spoon
Distilled water
Paper towels
Containers for collection of used sand

Experimental:

Part I: Adding water to Normal Beach Sand and Magic Sand©

- ☐ Place some paper towels in 2 of the trays.
- ☐ Take a spoonful of normal beach sand and make a pile on a paper towel in one of the trays.
- ☐ Take a spoonful of Magic Sand© and make a pile on a paper towel in the other tray.
- ☐ Using a disposable pipette gently place a few drops of water on the normal beach sand.
- ☐ Do the same with Magic Sand© placing a few drops of water on top.
- ☐ Record your observations in the table including a drawing.
- ☐ Add a few more drops of water to each and record your observations.

Table 1: Interaction of Water and Normal Beach Sand/Magic Sand When Water is Added to Sand

Observations	**Normal Beach Sand**	**Magic Sand©**
After a few drops of water		
After a few more drops of water		

What is ***the Lotus Effect***?

Explain what you just observed using the concepts of nanotechnology and the ***Lotus Effect***.

Part II: Adding Normal Beach Sand and Magic Sand© to Water

- ☐ Fill two 100 mL beakers with 60 mL of water.
- ☐ Sprinkle some normal beach sand into one of the beakers filled with water.
- ☐ Sprinkle some Magic Sand© into the other beaker filled with water.
- ☐ Record your observations in the table below (*include a drawing where appropriate and be sure to give it a title and label the rows and columns!*)

- ☐ Using a spoon, continue adding Magic Sand© into the beaker until the sand sinks to the bottom of the beaker, keeping track of how much sand you are adding.
- ☐ Add roughly the same amount of normal beach sand to the beaker.
- ☐ Record your observations in the table.

- ☐ Using the spoon, gently draw the clump of regular beach sand up the side of the beaker.
- ☐ Using a clean spoon, do the same with Magic Sand© and record your observations.
- ☐ Decant into the 500mL beaker as much of the water from the normal beach sand beaker as possible without pouring out the sand.
- ☐ Place some paper towels in one of the trays and pour the remaining normal beach sand and water into the tray. The paper towels will absorb the water. Feel the sand to determine if it is wet or dry.
- ☐ Record your observations in the table.

- ☐ Do the same thing with Magic Sand©, and decant into the 500mL beaker as much of the water from the magic sand beaker as possible without pouring out the sand.
- ☐ Place some paper towels in one of the trays and pour the remaining magic sand and water into the tray. The paper towels will absorb the water. Feel the sand to determine if it is wet or dry.
- ☐ Record your observations in the table.

- ☐ Place the normal beach sand and the Magic Sand© into the designated collection containers.
- ☐ Clean, dry, and return glassware and trays back to designated sites. Dispose of paper towels into the waste receptacle.

Table 2:

Was the normal beach sand wet? What about Magic Sand©? Using the terms ***hydrophobic*** and ***hydrophilic*** and concepts of nanotechnology, propose a possible explanation for this result.

Name___________________________________ Period____________
Date___________________

Activity 3: Exploring Properties of Normal Sand and Magic Sand©

Overview: In this activity, we will investigate properties of normal beach sand and Magic Sand© by adding sand to water and oil and understand how polarity plays a role.

Materials:

500 mL of Distilled water
500 mL of Mineral or vegetable oil
Balance
4 beakers
10 grams of normal beach sand
10 grams of Magic Sand©
Mixing rod

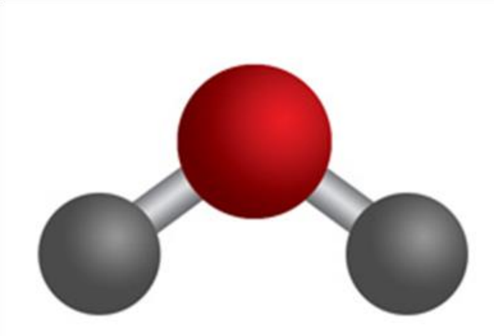
Experimental:

- ☐ Pour 250 mL of each solvent (water, oil) into 2 separate beakers. Label each beaker.
- ☐ Weigh out 5 grams of normal beach sand and place in each of the solvents.
- ☐ Wait 1-2 minutes and record your observations. Use the mixing rod to displace the sand and record any new observations.
- ☐ Repeat the last two steps using Magic Sand©.

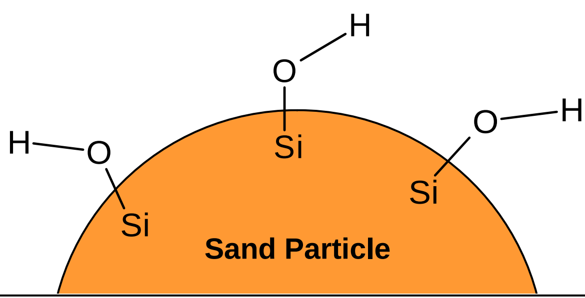
Table 1: Observations of Normal Beach Sand /Magic Sand in Water/Oil

Substance	Water	Oil
Beach Sand		
Magic Sand©		

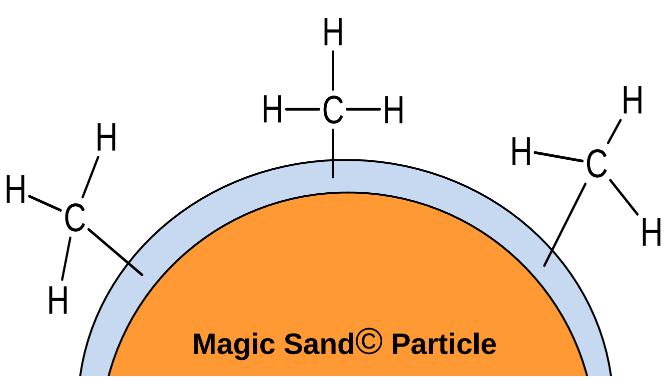
A ball and stick model of water is shown below. Label the atoms and partial charges on the water molecule. Explain what makes water molecules polar.



Chemical composition of sand particles is highly variable, but the most common constituent of sand is silica or silicon dioxide (SiO_2). Below is an illustration of what the sand particle surface may look like at the atomic level showing that it has –OH termination at the surface. Draw in water molecules and show how they would interact with the –OH groups at the surface of the sand particle. Be sure to show partial charges. Must these –OH groups be polar or non-polar?



Magic Sand© is essentially beach sand that is coated with particles of chemically treated silica. Each grain now has methyl groups (CH_3) attached to its exterior. What physical property must the methyl groups have to make the sand hydrophobic?



Oil also consists of molecules containing many methyl groups (CH_3). Using the terms ***polar*** and ***non-polar*** and concepts of nanotechnology, explain why normal beach sand and Magic Sand© behave the way they did in water and oil.

Using the concept of polarity, explain what makes normal beach sand hydrophilic and Magic Sand© hydrophobic.

Chemistry of Hydrophobic Sand – Vocabulary

<u>Define each of the terms below in your own words:</u>
If you are unsure, do some research to find out!

Polar bonds

Nonpolar bonds

Polar molecules

Nonpolar molecules

Hydrophobic

Hydrophilic

Intermolecular forces

Hydrogen bonding

Solubility rule—"like dissolves like"

Nanometer

Nanoscale

Nanotechnology

ANSWER KEY

Chemistry of Hydrophobic Sand – Pre-Activity and Post-Activity Questions

Pre-Activity Questions:

1. In the first activity, you will make your own "magic" sand by coating normal beach sand with a hydrophobic substance. How can you test to see if you have successfully made hydrophobic sand?
   Put some in water to see if it stays dry.
2. Predict what will happen when you put a droplet of water on a pile of Magic Sand©. Explain.
   The water droplet would bead up because water is a polar molecule and would be repelled by the hydrophobic surfaces of Magic Sand© particles.
3. Predict what will happen when you put normal beach sand and Magic Sand© in oil. Explain.
   Beach sand would clump together because its particles are hydrophilic and do not like oil which is hydrophobic. Magic Sand© would become dispersed and become wet because its particles are hydrophobic and so is oil.

Lab & worksheet completion by students in groups of 2 is ideal; however groups of 3-4 would also work.

Post-Activity Questions:

4. Why did normal beach sand get wet in water Magic Sand© stayed dry?
   Because normal beach sand particles are hydrophilic and Magic Sand© particles are hydrophobic.
5. What happened when you put droplets of water on a pile of Magic Sand©? Why?
   The observations will vary, but they should have observed the Lotus Effect.
6. Another use for Magic Sand© is for keeping household plants healthy. Can you think of how mixing some Magic Sand© in the soil can keep plants healthy?
   If the roots of a plant get too much water and not enough air, they can rot. Having some Magic Sand© in the soil can ensure dry spots in the soil and thus roots can get enough air.

Extensions:

1. Explain why water is a liquid and methane (CH_4) is a gas (at atmospheric pressure and room temperature).
   Because water molecules are polar and have strong intermolecular forces (hydrogen bonds) keeping the molecules close together to form a liquid, but methane molecules are non-polar and have very weak intermolecular forces and the molecules are farther apart.
2. Predict how normal beach sand and Magic Sand© would behave in methanol (CH_3OH). Explain.
   The answer that we are looking for is that they would both get wet in methanol because methanol has both hydrophobic and hydrophilic parts. But in reality, Magic Sand© would probably still be repelled by methanol.

Name___________________________________ Period____________
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Activity 1: Making Hydrophobic Sand

Overview: In this activity, we will be making our own "magic" sand by coating regular beach sand particles with silicone spray to make them hydrophobic.

Materials:

Normal Beach Sand
Silicone Spray or Scotch Guard
Baking Tray
Aluminum Foil
Newspaper
2 Cups or Beakers
Distilled Water
Spoon
Paper towels

Experimental:

- ☐ Cover the baking tray with aluminum foil
- ☐ Lay a couple layers of newspaper and put the baking tray on it. Be sure to do this outside or in fume hood where you have good ventilation.
- ☐ Put a layer of beach sand on the baking tray. Make sure it's an even layer.
- ☐ Take the silicone spray, and start spraying off the baking tray first and then spraying over the sand back and forth slowly covering the entire tray to get a thick coating.
- ☐ Gently shake the tray to stir the sand and then spread the sand to get an even layer again.
- ☐ Repeat the last two steps 4 times.
- ☐ Allow the sand to sit overnight.

Record your observations:

☐ Test both the original sand and the hydrophobic sand you created by taking a handful and dunking it in water in a separate cup or beaker.

☐ Scoop some out with a spoon and spread it on a paper towel.

Record your observations:

Did you succeed in making hydrophobic sand? Why or Why not?

Answers will vary, but it was successful if the sand stayed in clumps when put in water and stayed dry because this means that the sand particles became hydrophobic after the coating process.

Explain how you applied nanotechnology in making hydrophobic sand. Be sure to include an illustration with labels!

Nanotechnology was applied by modifying sand particle surfaces with a molecule that has both hydrophilic and hydrophobic parts. The hydrophilic part is going to stick to the sand surface and the hydrophobic part is going to provide the hydrophobic coating. This process occurs on a nanometer scale and is an example of how modifying surfaces at the nanoscale can change physical properties of materials. For an illustration, see Figure 3 in background information for an example.

How can you improve your process to make better hydrophobic sand?

Answers will vary depending on how well their hydrophobic sand turned out, but there is always room for improvement!

Name___________________________________ Period____________
Date___________________

Activity 2: Magic Sand© and Hydrophobic Effect

Overview: In this activity, we will investigate the interaction of normal beach sand and hydrophobic Magic Sand© with water by comparing how they differ when water is added to sand and when sand is added to water and observing their hydrophobicity.

Materials:

Normal beach sand
Magic sand ©
2-100ml beakers
500ml beaker
4 trays (about 15cm^2 x 3cm deep)
Disposable pipette
Spoon
Distilled water
Paper towels
Containers for collection of used sand

Experimental:

Part I: Adding water to Normal Beach Sand and Magic Sand©

- ☐ Place some paper towels in 2 of the trays.
- ☐ Take a spoonful of normal beach sand and make a pile on a paper towel in one of the trays.
- ☐ Take a spoonful of Magic Sand© and make a pile on a paper towel in the other tray.
- ☐ Using a disposable pipette gently place a few drops of water on the normal beach sand.
- ☐ Do the same with the Magic Sand© placing a few drops of water on top.
- ☐ Record your observations in the table including a drawing.
- ☐ Add a few more drops of water to each and record your observations.

Table 1: Interaction of Water and Normal Beach Sand/Magic Sand When Water is Added to Sand

Observations	**Normal Beach Sand**	**Magic Sand©**
After a few drops of water		
After a few more drops of water		

What is ***the Lotus Effect***?

The lotus effect refers to the very high repellence of water exhibited by leaves of the lotus flower. The surface of the leaves is very hydrophobic and water is repelled by it. Water droplets form beads on the surface and when they roll off, they pick up dirt along with them cleaning the leaves.

Explain what you just observed using the concepts of nanotechnology and the ***Lotus Effect***.

The observations will vary but, the water droplet either formed a bead or rolled off of the pile of Magic Sand© because the Magic Sand© has a nanometer scale hydrophobic coating on the particle surface and strongly repels water. When water comes in contact with the Magic Sand© particle surface, it is repelled similar to water on hydrophobic lotus leaves.

Part II: Adding Normal Beach Sand and Magic Sand© to Water

- ☐ Fill two 100 mL beakers with 60 mL of water.
- ☐ Sprinkle some normal beach sand into one of the beakers filled with water.
- ☐ Sprinkle some Magic Sand© into the other beaker filled with water.
- ☐ Record your observations in the table below (*include a drawing where appropriate and be sure to give it a title and label the rows and columns!*)

- ☐ Using a spoon, continue adding Magic Sand© into the beaker until the sand sinks to the bottom of the beaker, keeping track of how much sand you are adding.
- ☐ Add roughly the same amount of normal beach sand to the beaker.
- ☐ Record your observations in the table.

- ☐ Using the spoon, gently draw the clump of regular beach sand up the side of the beaker.
- ☐ Using a clean spoon, do the same with Magic Sand© and record your observations.
- ☐ Decant into the 500mL beaker as much of the water from the normal beach sand beaker as possible without pouring out the sand.
- ☐ Place some paper towels in one of the trays and pour the remaining normal beach sand and water into the tray. The paper towels will absorb the water. Feel the sand to determine if it is wet or dry.
- ☐ Record your observations in the table.
- ☐ Do the same thing with Magic Sand©, and decant into the 500mL beaker as much of the water from the magic sand beaker as possible without pouring out the sand.

- [ ] Place some paper towels in one of the trays and pour the remaining magic beach sand and water into the tray. The paper towels will absorb the water. Feel the sand to determine if it is wet or dry.
- [ ] Record your observations in the table.

- [ ] Place the normal beach sand and the Magic Sand© into the designated collection containers.
- [ ] Clean, dry, and return glassware and trays back to designated sites. Dispose of paper towels into the waste receptacle.

Table 2: *Interaction of Water and Normal Beach Sand/Magic Sand When Sand is Added to Water*

Observations	*Normal Beach Sand*	*Magic Sand©*
After sprinkling some into beaker with water		
After adding enough sand to sink the Magic Sand© into water		
After drawing a clump of sand up the side of beaker		

After decanting water and spreading the remaining sand on paper towel		

Was the normal beach sand wet? What about Magic Sand©? Using the terms ***hydrophobic*** and ***hydrophilic*** and concepts of nanotechnology, propose a possible explanation for this result. *Answers will vary, but normal beach sand should have been wet Magic Sand© stayed dry. This is because Magic Sand© has a nanoscale coating of hydrophobic material on the particle surface repelling water. Normal beach sand particles are hydrophilic on the hand which is why it was wet.* *This shows how modifications on a nanoscale can drastically change physical properties of materials.*

Name___________________________________ Period____________
Date___________________

Activity 3: Exploring Properties of Normal Sand and Magic Sand©

Overview: In this activity, we will investigate properties of normal beach sand and Magic Sand© by adding sand to water and oil and understand how polarity plays a role.

Materials:

500 mL of Distilled water
500 mL of Mineral or vegetable oil
Balance
4 beakers
15 grams of normal beach sand
15 grams of Magic Sand©
Mixing rod

Experimental:

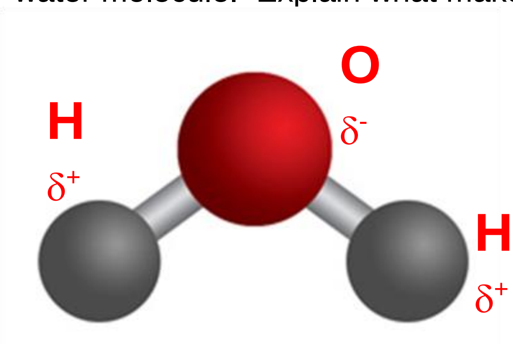
- ☐ Pour 250 mL of each solvent (water, oil) into 2 separate beakers. Label each beaker.
- ☐ Weigh out 5 grams of normal beach sand and place in each of the solvents.
- ☐ Wait 1-2 minutes and record your observations. Use the mixing rod to displace the sand and record any new.
- ☐ Repeat the last two steps using Magic Sand©.

Table 1: Observations of Normal Beach Sand/Magic Sand in Water/Oil

Substance	**Water**	**Oil**
Beach Sand		

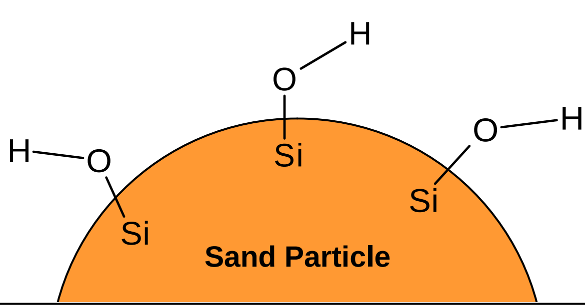
Magic Sand©		

A ball and stick model of water is shown below. Label the atoms and partial charges on the water molecule. Explain what makes water molecules polar.



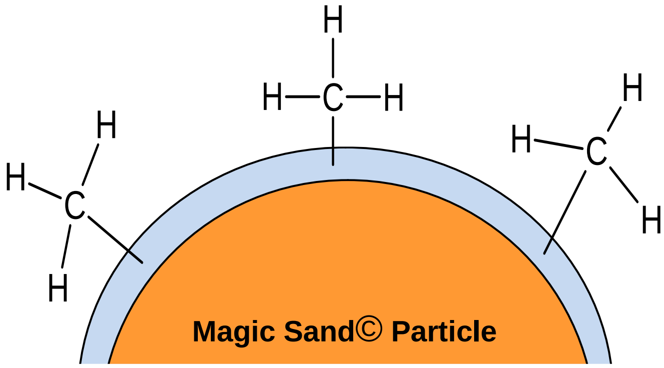
The electrons of a water molecule are shared unequally; oxygen holding a larger share, resulting in partial charges on the atoms, and the molecule has a bent structure causing the molecule to have a positively charged end and a negatively charged end making the molecule polar.

Chemical composition of sand particles is highly variable, but the most common constituent of sand is silica or silicon dioxide (SiO_2). Below is an illustration of what the sand particle surface may look like at the atomic level showing it has –OH termination at the surface. Draw in water molecules and show how they would interact with the –OH groups at the surface of the sand particle. Be sure to show partial charges. Must these –OH groups be polar or non-polar?



Answer should show partial negative charge on oxygen and partial positive charge on hydrogen, and water hydrogen bonding to the –OH groups on the sand surface (H on water to the O on –OH group and O on water to the H on –OH group) represented by a dotted line. Technically there should be 2 water molecules hydrogen bonded to each O. They must be polar because we know that sand particles are hydrophilic.

Magic Sand© is essentially beach sand that is coated with particles of chemically treated silica. Each grain now has methyl groups (CH_3) attached to its exterior. What physical property must the methyl groups have to make the sand hydrophobic?



The methyl groups must be non-polar because in non-polar molecules electrons are shared equally resulting in no partial charges and they do not interact with the partially charged atoms of water.

Oil also consists of molecules containing many methyl groups (CH_3). Using the terms ***polar*** and ***non-polar*** and concepts of nanotechnology, explain why normal beach sand and Magic Sand© behave the way they did in water and oil.

Molecules of oil are non-polar making them hydrophobic. Since normal beach sand particles surface has polar groups making it hydrophilic, it doesn't like oil and is repelled by it. Magic Sand© on the other hand is non-polar because it has a nanoscale hydrophobic coating and likes oil.

The opposite for water. Normal beach sand particle surface has polar groups making it hydrophilic and thus it likes water allowing for it to get wet. Magic Sand© on the other hand is non-polar because it has a nanoscale hydrophobic coating and hates water, thus causing it to repel water.

This shows how modifications on a nanoscale can drastically change physical properties of substances.

Using the concept of polarity, explain what makes normal beach sand hydrophilic and Magic Sand© hydrophobic.

The –OH groups on normal beach sand particle surface are polar making normal beach sand hydrophilic while the –CH_3 groups on Magic Sand© particle surface are non-polar making Magic Sand© hydrophobic.

Chemistry of Hydrophobic Sand – Vocabulary

Define each of the terms below in your own words:
If you are unsure, do some research to find out!

Polar bonds – bonds in molecules where the electrons are not shared equally

Non-polar bonds – bonds in molecules where the electrons are shared equally

Polar molecules – molecules that have a positively charged end and a negatively charged end.

Nonpolar molecules – molecules that do not have positively charged and negatively charged ends.

Hydrophobic – water loving

Hydrophilic – water hating

Intermolecular forces – interactions that occur between molecules

Hydrogen bonding – attraction among molecules that have hydrogen attached to an electronegative atom such as oxygen.

Solubility rule —"like dissolves like" – polar substances dissolves in other polar substances, and non-polar substances dissolve in other non-polar substances

Nanometer – $1x10^{-9}$ m or 1/1,000,000,000 m

Nanoscale – Relating to or occurring on a 1-100 nm scale

Nanotechnology – manipulation of matter on an atomic and molecular scale

Materials can be ordered through:

Consumables:

- (6) 1 lb jar of Hydrophobic Sand $7.54 (each) – Science Kit http://sciencekit.com/hydrophobic-sand/p/IG0024054/
- 5 lb bucket of Pacific Royal Blue Crayola Play Sand $6.99 (each) + $14.99 shipping http://www.coloredsandstore.com/online-store/
- (8) Scotch guard $5.33 (each) http://www.walmart.com/ip/Scotch-Guard-Fabric-And-Upholstery-Protector-10-oz/13281231
- (8) Baking Tray $3.98 (3 ct) http://www.walmart.com/ip/Hefty-EZ-Foil-Cake-Pans-With-Covers-3ct/17177487
- (1) Aluminum Foil $9.48 http://www.walmart.com/ip/Reynolds-Wrap-Aluminum-Foil-250-sq-ft/21129696
- (Stack) Newspaper
- (1) Mixing Rods or Plastic Spoons $2.84 (100 ct) http://www.walmart.com/ip/Great-Value-White-Spoons-100-ct/11979183
- (1) Trays or paper plates $5.97 (80 ct) http://www.walmart.com/ip/Dixie-10-1-16-Paper-Plates-80ct/17619717
- (1) 100/pkg Beral Pipet, Extra Long, Disposable Polyethylene, 225 mm x 5 mm $6.92 – Science Kit http://sciencekit.com/dropper-pipets-disposable-mdash-polyethylene/p/IG0026084/
- (1) 250/pkg Sustainable Earth by Staples® Multifold Paper Towels, White, 1-Ply, $29.99 (for 4,000/Case) – Staples http://www.staples.com/Sustainable-Earth-by-Staples-Multifold-Paper-Towels-White-1-Ply-4-000/product_887845
- (1) Vegetable Oil, 1Ga $7.36 http://www.walmart.com/ip/Great-Value-Pure-Vegetable-Oil-128-fl-oz/10451011
- (2) Water, 1 Ga $0.99 http://www.walmart.com

Non-Consumables:

- (2) 100 mL Beakers* $34 (10 pk) http://www.fishersci.com/
- (2) 500 mL Beakers* $49.50 (6 pk) http://www.fishersci.com/
- (4-8) Container for collection of used sand or bucket $4.97 (each) http://www.walmart.com/ip/Carrand-CRD94102-8-Quart-Bucket/25063398
- (1) Balance (if you don’t have one, you can use any kitchen scale that can weigh in grams)

*100 mL beakers can be substituted with cups and 500 mL beakers can be substituted with plastic containers

Summary

In this activity your students will have learned the structure and properties of water, differences between polar and non-polar molecules, and how their polarity affects intermolecular forces, and solubility and hydrophobic effect by synthesizing and exploring properties hydrophobic sand as compared with regular beach sand.

Disclaimer

Activity Evaluation

The Northeast Advanced Technological Education Center (NEATEC) would like your feedback on this activity. Your feedback allows NEATEC to maintain the quality and relevance of this activity.

To provided feedback, please email E.Crimmel@hvcc.edu

Your feedback is greatly appreciated.

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