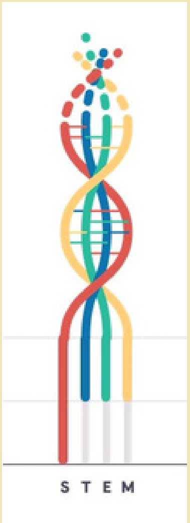
The amazing properties of Aerogel



Abstract

At this STEM project students challenge to investigate the new material silica Aerogel through learning activities based on the guided Inquiry Learning approach to promote students' motivation to learn about Advanced Materials from different disciplines: Mathematics, Physics, Chemistry and Engineering.

Keywords

nanomaterial, nanoscale, surface area, volume area, superhydrophobic surface, self-cleaning surface, oil spill clean-up, superinsulation

For whom?

age: 15-17y

Central Wondering

Why scientists made the amazing material called Aerogel?

Summary

Students experiment with a new synthetic (human-made) material called Aerogel. Aerogel commonly called "frozen smoke", is a super-material with some amazing properties!

In a simple and fun way, students learn about density and the material effects of surface area. Furthermore, students learn about basic heat transfer and how aerogel is a great thermal insulator. Students also learn about a wide array of Aerogel applications, such as hydrophobic properties and applications for self cleaning surfaces!

Why scientists made the amazing material called Aerogel?

Module 1: What is nano? How small is nano?
Module 2: Is there any connection between the size and surface area of objects?
Module 3: Introducing Aerogel
Module 4: Thermal Insulator- Superinsulation
Module 5: Superhydrophobic/Self-cleaning surface

Why scientists made the amazing material called Aerogel?

Table of Learning Activities

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2. Is there any connection between the size and surface area of objects?	• Set the Scene • Philosofical conversation • Exploring -Make some assumptions about the connection between the size of the objects and their surface area. • Get to work • Raising wondering questions • What does our scientist say?
3. Introducing Aerogel	• Set the Scene • Philosofical dialogue • Short links to history • Raising wondering questions • On discovery • Get to work
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5. Superhydrophobic/Self-cleaning surface	• Set the Scene: • Philosofical dialogue • On discovery • Get to work • Raising wondering questions • What does our scientist say?

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1.What is nano?

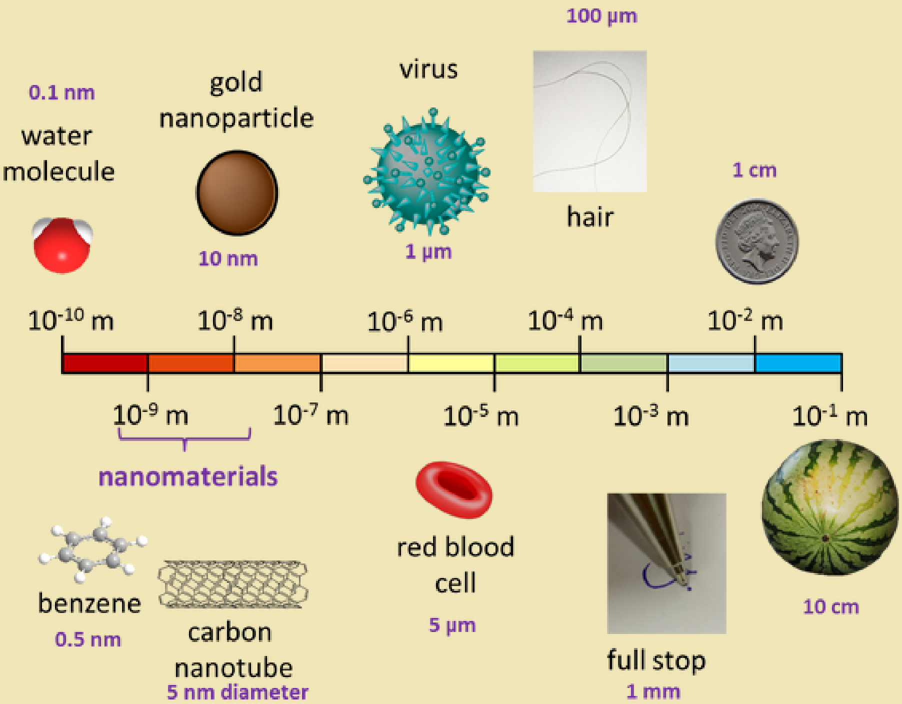
Set the scene

Show the video:

Exploring!

Let's play a game!

For each group of students give the 10 images of the picture below and call them to put them in order from the smallest to the biggest:



What does our scientist say?

A nanometer is one-billionth of a meter (1/1,000,000,000)

- A sheet of paper is about 100,000 nm thick.
- A human hair measures roughly 50,000 - 100,000 nm across.
- Your fingernails grow 1 nm every second.
- A virus is about 70 nm long
- A cell membrane is about 9 nm thick.
- 10 hydrogen atoms are about 1 nm.

Nanoscale refers to measurements of **1 – 100 nanometers**

At the nanoscale, many common materials exhibit **unusual properties**, such as remarkably lower resistance to electricity, or faster chemical reactions

Nanotechnology is the manipulation of material at the nanoscale to take advantage of some properties. This often means working with individual molecules

Nanoscience, nanoengineering and other such terms refer to those activities applied to the nanoscale. “Nano,” by itself, is often used as short-hand to refer to any or all of these activities

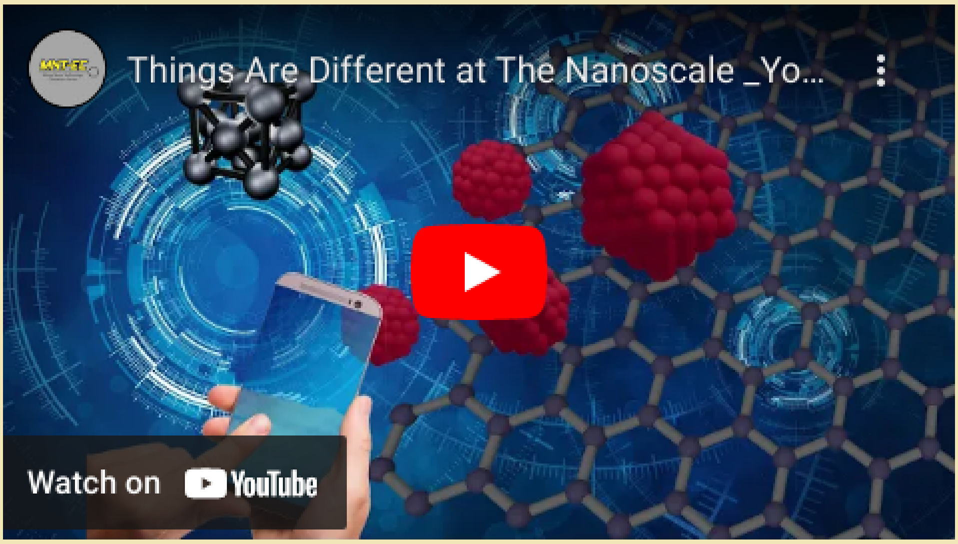
Nanomaterials operate at incredibly small scales and possess unique properties that have wide-ranging applications.

By **manipulating the surface area** of nanomaterials, scientists and engineers can develop innovative solutions in various fields.

2. Is there any connection between the size and surface area of objects?

Set the scene

Show the video:

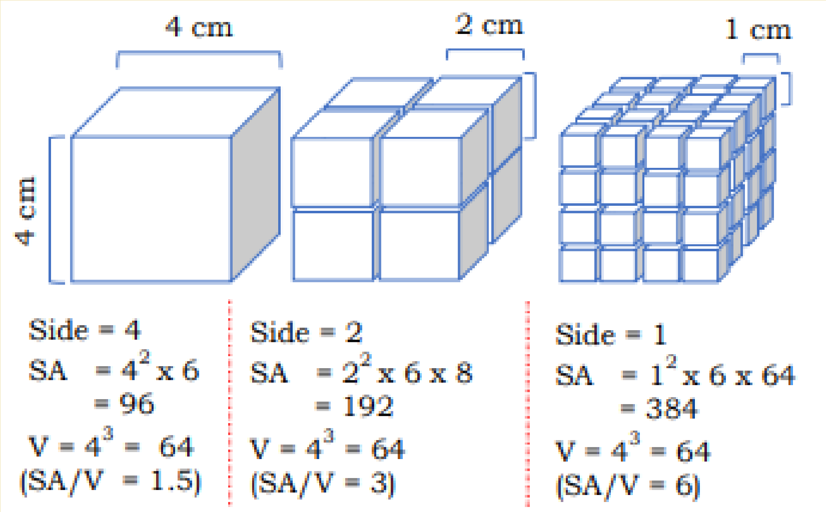


Raising Wondering Questions

- How does the surface area change as the size of the cube decreases?
- How does the volume change?
- What implications does this have for nanoscale materials?
- How do you think the size and the surface of objects connect to advanced materials and nanotechnology in general?
- Why materials can exhibit unique properties and behaviors that differ from their bulk counterparts?
- Do you remember how we calculate the surface area and volume of objects in cubic objects?
- How do you think the size or the volume of the objects are related to the surface area? Is there any relation between the two?
- What do you think,as the size of the cube side decrease, does the surface area increase or decrease?

Exploring!

Make some calculations!



1. Calculate and compare the surface area and volume of a cube with side:

- 4 cm
- 2 cm
- 1 cm

What do you observe?

2. Compare the surface area to volume ratio (surface/volume) for each cube.

What do you observe?

Raising Wondering Questions

- After making the calculations, what do you observe?
- Why we take into consideration and the volume of the cube except from the surface area?

Students are asked to discuss how a chemical reaction occurs based on guiding questions such as:

- What causes a chemical reaction to take place?
- Where do most of the chemical reactions take place?
- Can the atoms or molecules inside a bulk material react?

What does our scientist say?

Only the atoms or molecules at the surface can react.

When a particle it's broken down into smaller pieces the **total surface area increases.**

Objects that have a **higher surface area** have more chances for **chemical reactions** to take place than objects with a lower surface area. So this can **increase the rate of reaction.**

Why we measure the Volume, too?

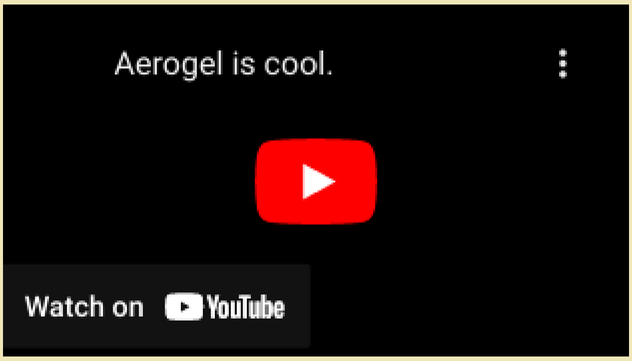
- The volume of a material affects its bulk properties and storage capabilities.
- In many cases, the desired functionality of nanoscale materials relies on their internal structure and the ability to store or encapsulate substances within their volume.
- For instance, nanoparticles used in drug delivery systems need sufficient volume to accommodate therapeutic agents.
- Additionally, the volume influences properties like **electrical conductivity, thermal conductivity, and mechanical strength, which can be crucial in various applications.**

So, because the high surface to volume ratio, at nanoscale materials begin to exhibit unique properties that affect physical, chemical and biological behaviour!

3. Introducing Aerogel

Set the scene

Show the video:



Show the video:

Aerogel is 99.8% air by volume, making it the lightest solid known to humans!

The man who invented aerogel, Samuel Stephens Kistler, was a chemical engineer who published his findings in a 1931 edition of the journal, Nature. Since then, his discovery has been applied to a wide variety of uses
Creative engineers of many specialties take advantage of the extreme properties of the aerogel—high surface area, low density, low thermal conductivity, robustness, etc.—to best suit their designs.

Alternatively, show the presentation "Aerogel properties"

Raising Wondering Questions

- Does anyone have any ideas about what might be some properties of the aerogel?
- Do you think aerogels are heavy or light?
- Do you think that aerogels are strong or do you think they break easily?
- Do you think that aerogels are heavy or light?
- Aerogel is also a great thermal insulator. Does anyone know what I mean by that?

On discovery!!

We will explore some additional awesome properties of aerogels and we will look at how engineers use aerogels in a wide variety of applications

- Ask students to start thinking of their own ideas for good purposes to use Aerogels
- Assign students to conduct Internet research on aerogel-containing products.
- Ask them to each write-up and share with the class one interesting aerogel application, describing how the aerogel properties contribute to the product benefits

Examples:

- Hairspray Clothing
- Footwear
- Kitchens and home construction
- Water absorption
- Shock absorption
- Sound insulation
- Medical products such as wrist wraps
- Cell phones
- Tennis racquets
- Military use Fire retardants
- Thermal insulation in vehicle parts

4. Thermal Insulator- Superinsulation

Set the scene

What factors affect the thermal conductivity of materials?

Raising Wondering Questions

- What materials do we use when we want high thermal conductivity?
- What materials do we use when we want thermal insulation?

On discovery!!

Without Aerogel

Materials needed:

- Two identical cups (preferably transparent or semi-transparent)
- Two thermometers
- Insulation materials like cotton balls, foam, or bubble wrap
- Hot water
- Timer or clock

1. Fill both cups with hot water from the same source to a similar level. Ensure the water is hot but not scalding. Caution the students to handle hot water carefully.
2. Before starting the experiment, allow a few minutes for the hot water to heat the cup and insulation materials evenly.
3. Instruct the groups to place a thermometer in each cup, making sure they do not touch the cups' sides or insulation material.
4. Ask the students to record the initial temperature readings of both thermometers.
5. Start the timer and ask the students to observe and record the temperature readings of both cups every minute for the next 10 minutes.
6. After 10 minutes, have the students analyze and discuss the temperature data they recorded.
7. They should notice that the cup with the insulation material has retained more heat and has a highe temperature compared to the cup without insulation.

Raising Wondering Questions

- Engage the students in a discussion about their observations.
- Emphasize that the insulation material prevented the heat from escaping the cup, thus keeping the water warmer for a longer duration.
- Connect the experiment to aerogel by explaining that aerogel, due to its extremely low density and porous structure, is an exceptional insulator that effectively prevents heat transfer.
- Conclude the workshop by summarizing the key points about insulation and the remarkable properties of aerogel.
- By using this experimental setup, students can witness the effects of insulation firsthand and understand the basic principles behind aerogel's superior insulating capabilities, even without directly working with the material itself

Now, students are exposed to learn more about the insulation property of silica aerogel!

Using Aerogel

Show the video:

They experiment with aerogel tapes.
The tapes can be bought from: https://rovashield.com/

They will need per team of 4 students:

- 1) Aerogel tape 25 cm x 25 cm
- 2) Gas lighter
- 3) graber
- 4) A flower

1. Put the flower up to the Aerogel sheet
2. Grab it with the grapper
3. With the gash lighter burn the other side of the Aerogel sheet, as shown to the video

Raising Wondering Questions

1. Students discuss of their observations by the guided questions:
2. What happened to the flower when we heat the Aerogel sheet?
3. What are the factors which contribute to Aerogel's thermal conductivity?
4. How is the structure of Aerogel which affect its thermal conductivity?

How Aerogel could be a superinsulation material?

They are expected to be able to explain the concepts of the superinsulation property of Aerogel and its advantages considered as a nanoporous material, thermal insulation properties of materials, and heat transfers including the heat convection, conduction, and radiation,

Students are asked to explain their knowledge gaining form this experiment.

Students are asked to purpose the ideas of the applications of using silica aerogels as a superinsulation material in daily life.

- How to apply the applications of using silica aerogels as a superinsulation material in daily life?

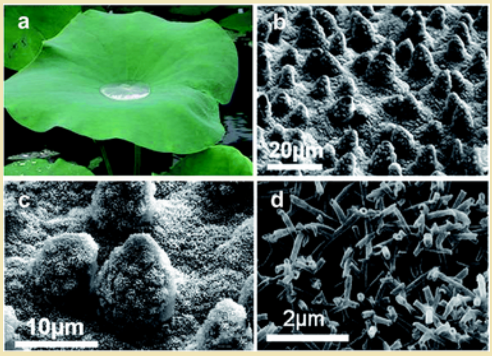
5. Superhydrophobic/Self-cleaning surface

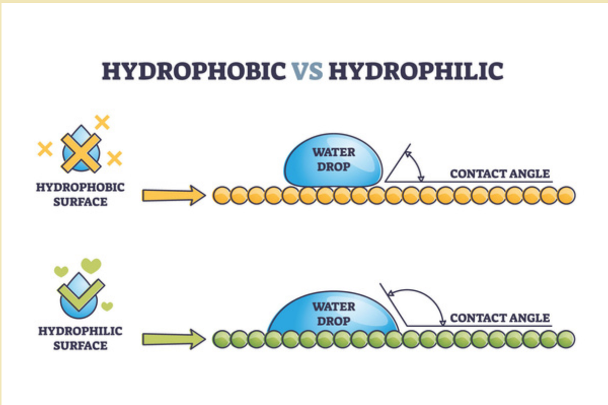
Set the scene

Have you ever noticed how water rolls off a leaf, or how a lily pad floats on water?

These plants parts are said to be “superhydrophobic” and their leaves never get dirty.

Why is this?





Philosophical dialogue

Engineered hydrophobic surfaces are in high demand for many products and industries. For example, hydrophobic surfaces are optimal for sweat-proof and dirt-proof clothing, rust prevention, anti-icing, solar panels and even sanitation.

Maybe we can convert a surface which absorbs water or stick to it dirt, to a self cleaning surface!

On discovery!!

First, let us define hydrophobic: “hydro” means water and “phobic” means fear.
Think about oil and water.
Do they ever mix?
No, because oil is “hydrophobic” – the oil appears to avoid the water!
What happens to the leaves? Do you have any idea?

Get to work!

You will need per 4 students:

- 2 pieces of cardboard 25 cm x 25 cm
- 1 aerogel tape
- 1 pipete
- A glass of water

The tapes can be bought from: https://rovashield.com/

Students prepare a self-cleaning surface by coating a glass slide with aerogel tape.

At first experiment:

1. They coat a piece of cardboard paper 25cm x25cm with the Aerogel tape sheets.
2. They rinse 1 drop of water
3. They observe the self-cleaning surface property of the surface by tilted the coated- surface at approximately 10 to 45 degree angle and dropped water on the coated-surface
4. They write down their observations

At second experiment:

1. They coat a piece of cardboard paper 25cm x 25cm with the Aerogel tape sheets.
2. They springle the paper with pencil dust
3. They rinse 1 drop of water
4. They observe the self-cleaning surface property of the surface by tilted the coated- surface at approximately 10 to 45 degree angle and dropped water on the coated-surface
5. They write down their observations

Materials needed:

1. Two identical small dishes or plates
2. Cooking oil (such as vegetable oil)
3. Water
4. Marker or pen
5. Timer or clock

Procedure:

1. Begin by introducing the concept of superhydrophobic surfaces and self-cleaning properties. Explain how certain materials can repel water and prevent liquid from sticking to their surfaces.
2. Divide the students into pairs or small groups and provide each group with two dishes or plates.
3. Instruct the groups to draw a small circle or shape in the center of one dish using a marker or pen. This will represent a dirty or contaminated spot.
4. Demonstrate to the students how to apply a thin layer of cooking oil to the surface of the other dish or plate. Make sure the oil covers the entire surface evenly.
5. Once the oil is applied, ask the students to predict what will happen when water is poured onto both dishes. Encourage them to think about how the oil-coated surface may behave differently from the regular dish.
6. Start the timer and pour a small amount of water onto both dishes simultaneously. Observe and discuss the results.
7. The students should notice that the water on the regular dish spreads out and wets the surface, while the water on the oil-coated dish forms into droplets and rolls off easily, leaving the surface clean.
8. Engage the students in a discussion about their observations. Ask them why they think the water behaved differently on the oil-coated surface compared to the regular one.
9. Explain that the thin layer of oil on the dish creates a hydrophobic barrier, preventing water from adhering to the surface. This is similar to the superhydrophobic or self-cleaning properties exhibited by aerogel.
10. Conclude the workshop by summarizing the key points about superhydrophobicity and self-cleaning surfaces. Highlight that aerogel, with its unique nanostructure, can exhibit these properties, making it useful in various applications such as waterproof coatings and stain-resistant materials.
11. Through this experiment, students can grasp the concept of superhydrophobic surfaces and gain an understanding of how aerogel can exhibit similar properties, even without direct access to the material itself.

Raising Wondering Questions

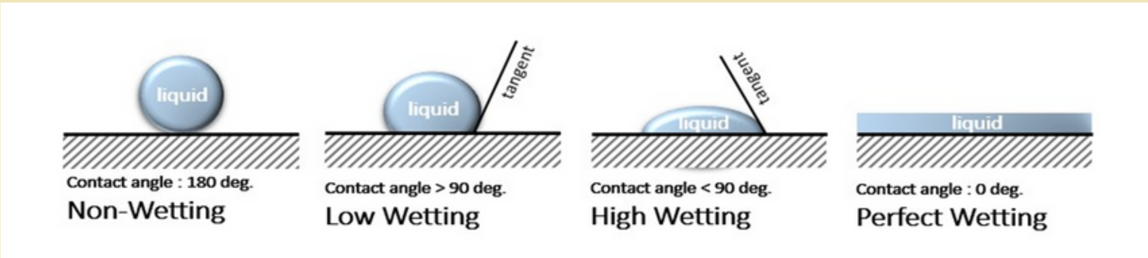
Students present their findings.

- What happend when we rinse the aerogel surface with water?
- What happenes to the dust when water rolled down through the dust?
- How the superhydrophobic surface relate to the self-cleaning surface property?

What does our scientist say?

Superhydrophobic Surfaces

High Contact Angle and Low Roll Off Angle Aids in Cleaning



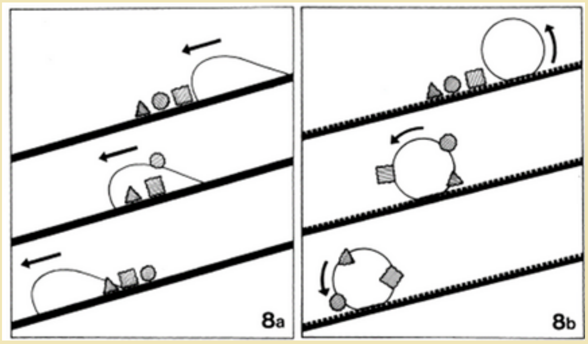


Diagram of water on tilted surface

Researcher adds more concepts and confirms the corrected explanation of the principle of superhydrophobic surface which consists of two components as a rough-surface and hydrophobic material coating on the rough-surface