An IBL Approach to the Surface Area to Volume Ratio and its Implications to the Nanomaterial Properties

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Nanotechnology is a science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometres. It is an important area as the same material may exhibit very different properties at the nanoscale from the properties of the bulk material. Nanotechnology is a dynamically developing scientific field of this century. Many nanomaterials and nanoproducts are currently used in our daily life in various ways. Thus, it is important to educate people and students about them, but also about their benefits, risks, as well as about social and ethical aspects of nanotechnology. Nanoscience and nanotechnology offer teachers the opportunity to bring the latest scientific knowledge and new technologies to the classroom. There are many "hands-on" activities and experiments which can demonstrate fundamental effects at the nanoscale and properities of nanomaterials in our macro-world. Therefore, teaching nanoscience and nanotechnology at the secondary school level offers opportunities for an inductive method as an inquiry-based learning. Nanotechnology is a multidisciplinary field where science disciplines such as physics, chemistry, biology, engineering and material science are included and inseparable. Through nanotechnology teachers get an unique opportunity for the interdisciplinary collaboration.

Introduction

This teaching module introduces one of the main ideas of nanoscience and nanotechnology – the size-dependent properties as surface-dominated properties. If the bulk material is divided into smaller and smaller objects and the total volume remains the same, the general surface area is dramatically increased. Some properties that occur at the surface will become magnified at the nanoscale, for example the melting point, rate of reaction, capillarity action, and adhesion. The teaching module consists of several parts.

Methods

In our teaching module we do not want to simply present the ready-made knowledge about the surface-dominate properties to students but students are actively learnt. We utilize the pedagogical method of inquiry-based learning [1]. It is a process where students involved in their learning, create questions, inquire widely and then build new understandings, meanings and knowledge. That knowledge is new and may be used to answer a question, to develop solution or to support a position. The knowledge is usually presented to others. Using this method can help students become more creative, more positive and more independent, responsible to organize their own work.

Teaching module description

Goals:

Students will be able to explain:

1. how the change of material size affects the reactivity rate
2. the concept of surface area to volume ratio (SVR) for different obejct shapes
3. the importance of microporous materials in nature
4. the environmental applications of nanotechnology

Students will be able to demonstrate:

5. basic properties of zeolites

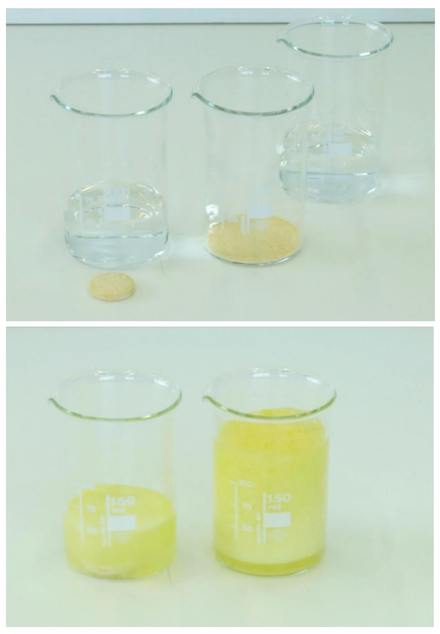
Duration: 90 minutes

Materials and tools: beakers, Petri dish, water, mortar, sparkling tablets, play dough, paper model of zeolite, water from aquarium, zeolites, digital thermometer/multimeter, pH sensor or pH test/indicator paper, test tubes

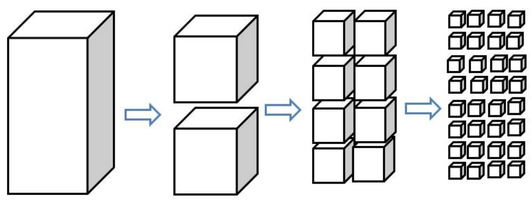
Grade(s): lower secondary (grades 6-9)/upper secondary (grades 1-3)

Part 1: Motivation experiment

Prepare two effervescent tablets and two same beakers with the same volume of water. Insert whole tablet to first beaker. Crush second tablet to a fine powder and insert to second beaker. Observe reactions in each beaker.



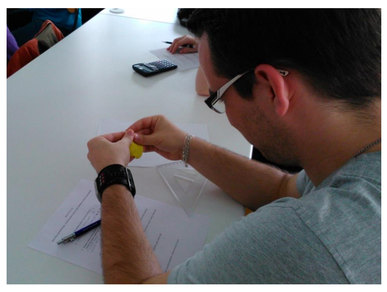
By cruching a tablet into smaller pieces, we get a larger surface area with same volume and its rate of dissolution is increased.

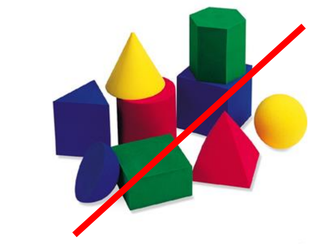


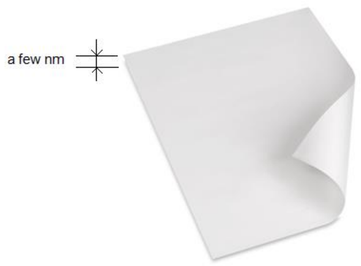
LARGER SURFACE = BIGGER REACTIVITY

Part 2: Discoveries I.

Let us look for the shape of the object in which we get the greatest possible surface area! Students work with play dough and try to find the right shape with the largest surface area.



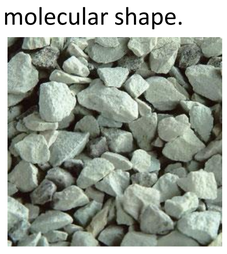


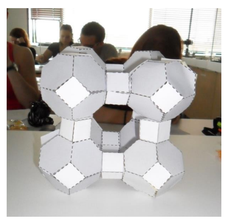


We obtain the largest surface area when we get **a thin sheet of material with a thickness of only a few atoms** (approximately several nanometers)! We introduce the concept of nanoscale or we recall it from a previous lesson.

Part 3: Discoveries II.

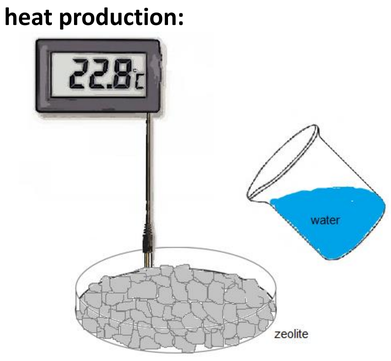
Nature and also people create materials with large surface area and effective shape. These materials are called microporous. We introduce **zeolites** – natural microporous materials – and we can model their molecular shape.



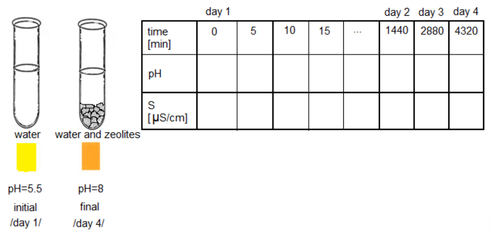


Let us discover amazing properties of these materials [2] with two simple experiments:

a) heat production:



b) pH and electrical conductivity changes:



	day 1					day 2	day 3	day 4
time [min]	0	5	10	15	...	1440	2880	4320
pH								
S [μS/cm]								

(the best way is to use water from aquarium)

Part 4: Excursion to the Lab

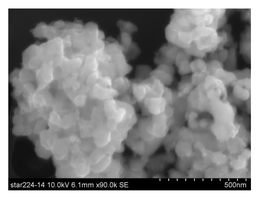
Laboratory in Regional Centre of Advanced Technologies and Materials Palacky University in Olomouc, Czech Republic

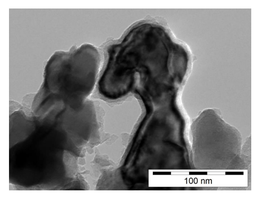
This is the laboratory for characterization of solid samples using the gas sorption method. Laboratory offers the physisorption measurment for the specific surface area determination with the determination of micropores widths of the porous materials and detailed analyses for characterization of the samples with very high surface area.
The term **sorption** encompasses both processes – adsorption and desorption. Adsoption is a surface-based process.

In this part students may implement the excursion to the laboratory in Regional Centre of Advanced Technologies and Materials in Olomouc in Czech Republic or in the nearest Nanocetre in Czech or Slovak Republic. If it is not possible, students could implement the virtual tour in this laboratory we are currently working on.

Part 5: NANO enhancements

Due to their microporous structure, zeolites are widely used in many environmental applications [3], e.g. odour control, absorbents for oil and spills, gas separations, radioactive site remediation/decontamination, water filtration, wastewater treatment and heavy metal removal.
But also other types of nanoparticles are synthesized for environment remediation and treatment (iron nanoparticles, silica-titania nanocomposites, dendrimers, magnetic nanoparticles, etc.) [4].



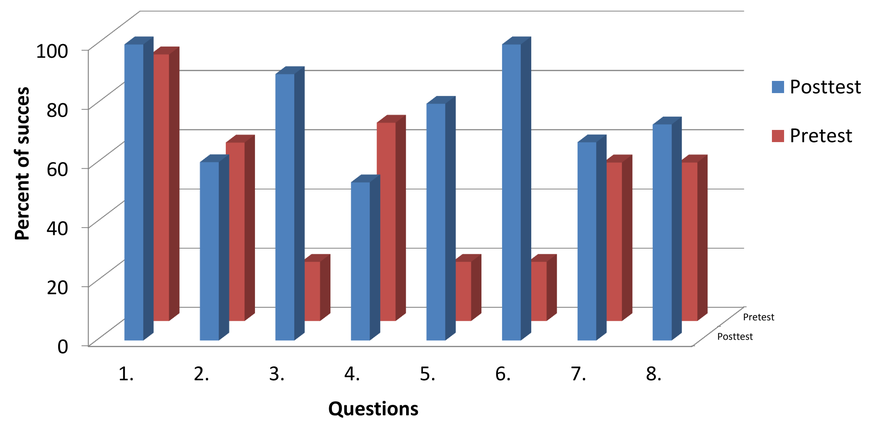


Microscopical analysis
zero-valent iron nanoparticles
for environmental applications.
(RCPTM UP Olomouc, CZ)

Results

Pretest and posttest:
Some questions can have two right answers.

1. How many nanometers are there in one meter?
   a) 1 000 000
   b) 1 000 000 000
   c) 1 000 000 000 000
2. Which objects do not belong to the nanoworld (1 – 100 nm)?
   a) virus
   b) atom
   c) bacteria
3. As material becomes smaller and approaches the nanoscale
   a) the surface-to-volume ratio and reactivity decrease
   b) the surface-to-volume ratio and reactivity increase
   c) the surface-to volume ratio increases and reactivity decreases
4. The increase in the surface-to-volume ratio of nanoscale materials relates to properties such as
   a) conductivity
   b) melting point
   c) rate of reaction
5. The microporous material (such as zeolite) is material
   a) with a small surface area
   b) with a large surface area
   c) the surface area can not be determinated
6. The adsorption is
   a) the adhesion of atoms, ions, or molecules of gas or liquid to the surface of solids
   b) the absorption of atoms, ions, or molecules of gas to liquid
   c) the release of atoms, ions, or molecules of gas from liquid
7. The adsoprtion is used for detection of
   a) porous structure of material
   b) surface area of material
   c) mass of material
8. The nanomaterials with a large surface area are used as
   a) insulators
   b) catalysts
   c) sorbents



Conclusions

This teaching module was checked on a group of phyciscs students. Students enjoyed active approach and appreciated the new knowledge about one of the main ideas of nanoscience and nanotechnology. Czech and Slovak students do not know too much about this technology.
We plan to test a larger group of high school students and modify the test. For better assessment of the test (and success of teaching module) it is necessary to have only one correct answer and more options.

References

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