A Guided Learning Introductory Course on Nanotechnology for Secondary Schools

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Abstract
Nanomaterials are objects of intensive research in different scientific domains and often called the future technology of the 21st century. Thus, it seems important that today's students become more familiar with this topic. In order to introduce the topic in school chemistry education contexts and to provide science teachers, who are mostly unaware of this topic, with teaching materials, a teaching unit on nanotechnology has been developed. The unit has been constructed based on a Guided Learning Concept. It was designed for chemistry lessons in secondary schools referring on educational standards of the regular German curriculum. The unit focuses on zinc oxide nanoparticles and will be described in detail in this paper. It has been conducted in two different classes in secondary schools.

1. Introduction

Nowadays, nanotechnology and nanomaterials can be found in many everyday products such as ketchup, socks and hard drives [1]. Since nanotechnology is one of the most important areas of modern research, it appears to be worthwhile to familiarize pupils with this topic, especially considering its future relevance.
To accomplish this, a teaching unit has been developed based on a Guided Learning Concept [2]. Within this concept, students work with a study book which contains all the necessary information to complete the tasks allowing students to learn about „nano" by themselves and at their own pace. The teacher has the role of a moderator, structuring the lessons and helping the students should any problems arise. The teaching unit and its four sub-units are displayed in Figure 1.

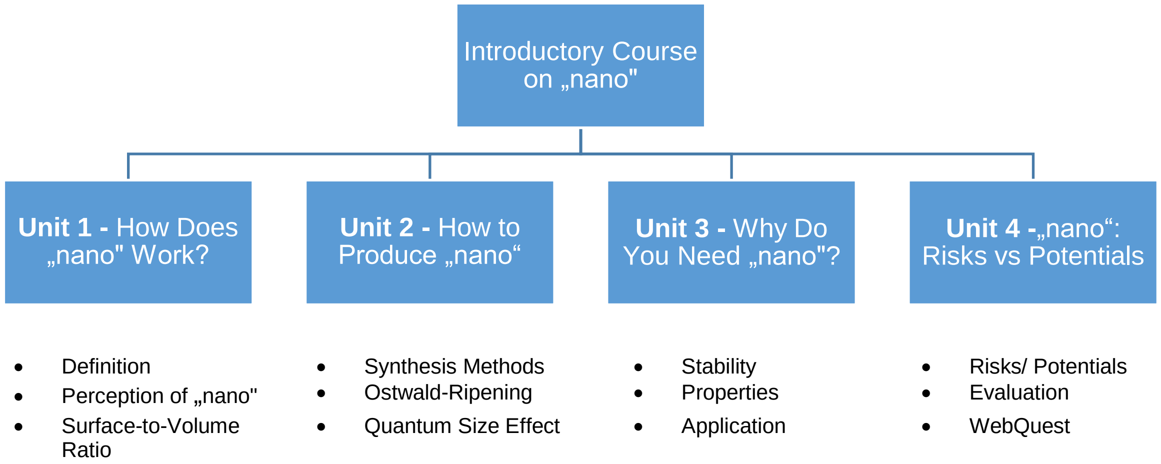


Figure 1: *Overview of the teaching unit*

2. Unit 1 - How Does „nano" Work?

The first sub-unit deals with the definition of the term „nano" including the interdisciplinary character of nano science, the size and the specific surface-to-volume-ratio of nanomaterials. Based on these three topics, the unit is divided into smaller units.
In the first sub-unit, the students concern themselves with their own understanding of the term „nano". Their first task is to create a Mind-Map [3] collecting all associations the students might have regarding „nano". After that, advertisements of products that include the term „nano" are presented to the students in the study book. While some of the advertisements are related to products based on nanotechnology, others are not. The student's task is to distinguish one from the other. In doing so, misconceptions regarding „nano" will be revealed to students so that they can correct them. The first

part of the chapter concludes with a short text about nanotechnology which includes the definition of „nano".
In the second sub-unit, the size and the perception of the nanodimension will be addressed. For that, the students have to work with a number line, which is presented in Figure 2.

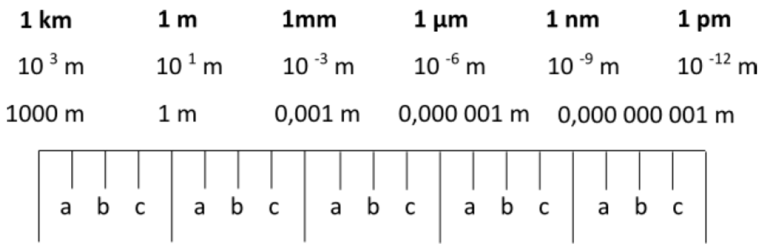


Figure 2: *Number line, used to get an overview of units of length*

The students have to fill in the blank spaces on the number line and assign different objects (a hair, a skyscraper, etc.) to it. In a second step, they have the task to estimate the size of different subjects in the nanodimension (a drop of blood, DNA, atoms, etc.) and to bring them in the correct order. They can compare their results with the solution given in the study book. Both tasks aim at improving the student's conception of the nanodimension. Finally, the students are encouraged to link the macroscopic and the microscopic dimensions by calculating how many nanoparticles (Ø125 nm) fit into the diameter of a human hair (100 µm).
In the third and last sub-unit, the students learn more about the surface-to-volume-ratio of nanoscaled materials. Their specific properties will be deduced from their large surface. In order to accomplish this, a model experiment [4] is used in the study book (s. Figure 3).

Figure 3: *Model experiment on the increase of the surface-area [4]*

Here, a cube is divided into eight smaller cubes by cutting each edge into half. This is done continuously. The students' task is to calculate the amount of cubes after the division, the respective length of the edges and based on this the over-all surface area assuming that the original cube had a size of 1 m^3. With each division of the edges, the surface area of the cube increases. This is depicted in a diagram (see Figure 4) [5].
The students deduce that the biggest increase of the surface area takes place when the length of the edges reaches the nano dimension (indicated by the lines). With this experiment, the students shall understand why nanoparticles have a much bigger surface-to-volume ratio than their macroscopic counterparts. At the end of this unit, the specific properties of atoms and molecules fixed to the surface of a particle are explained. Since over 90 % of the atoms or molecules in nanoparticles are surface atoms, they determine the properties of the whole nanoparticle.

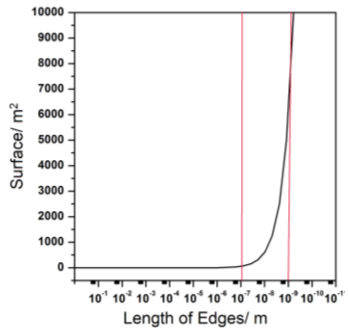
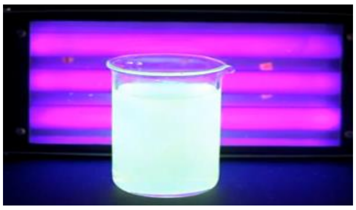


Figure 3: *Diagram showing the increase of the surface area*

3. Unit 2 - How to Produce „nano”

In the second unit, the focus is placed on the production of nanoparticles. In the first experiment, the students produce zinc oxide nanoparticles in a precipitation reaction [6]. Upon exposure to ultraviolet radiation, these particles emit a yellow-greenish fluorescence that can only be observed in the nanodimension with a particle size between 5,5 and 7 nm [7].

$$Zn^{2+}_{(sol)} + 2\ CH_3COO^-_{(sol)} + 2\ Na^+_{(sol)} + 2\ OH^-_{(sol)} \rightarrow$$
$$ZnO_{(s)} \downarrow + 2\ CH_3COO^-_{(sol)} + 2\ Na^+_{(sol)} + H_2O_{(l)}$$



Nanoparticles

Figure 4: *Synthesis of zinc oxide*

The phenomenon of the fluorescence will be explored by the students themselves using the study book. For this, different tasks have been developed. First of all, students learn more about different ways of producing nanoparticles (top-down and bottom-up methods). This knowledge is then used to determine how particles are produced in our experiment. After working on the chemical equation for the reaction, the following diagram is used to demonstrate the processes leading to fluorescence and to name the different parts involved in it.

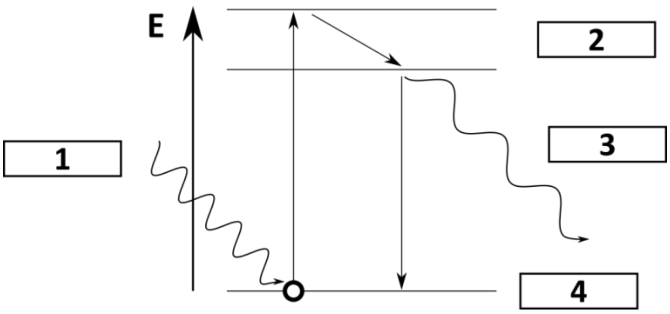


Figure 5: *Diagram used to explain the processes during fluorescence*

Information cards from the study book on the topics “light, wave length and energy” and “electron excitation” can be used to help with the tasks. The tasks aim for explaining the processes of the excitation and the light emission, especially the reason for the energetic difference between induced and emitted light.
The fact that the fluorescence is nano-specific is shown in a second experiment. The nanoparticle solution is boiled with a little bit of water so that the particles grow showing the accompanying decrease of light emission.

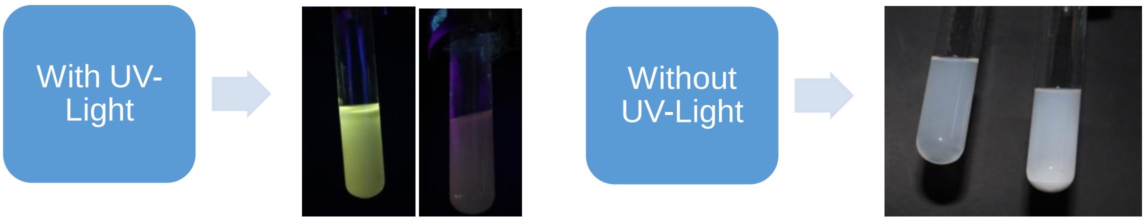


Figure 6: *Decrease of light emission and precipitation of the particle solution*

The tasks following the experiment again aim for the explanation of these processes. The growth of the particles is deduced from the visible precipitation of the particle solution. To explain this, the students read a text concerning the process of the Ostwald-ripening, the basis of nanoparticle growth. The correlation between particle size and fluorescence can be explained with the quantum-size effect on which there is a text in the study book as well.

4. Unit 3 - Why Do You Need „nano"?

In the third unit, the students learn about specific properties of nanoparticles and their use in everyday life. Here, they conduct an experiment [6] on the photocatalytic activity of zinc oxide nanoparticles. In this experiment, the students elaborate which factors (UV-light, zinc oxide nanoparticles) influence the decolourization of a green malachite solution. The experiment shows that zinc oxide nanoparticles and ultra violet light decolorize the solution most quickly.

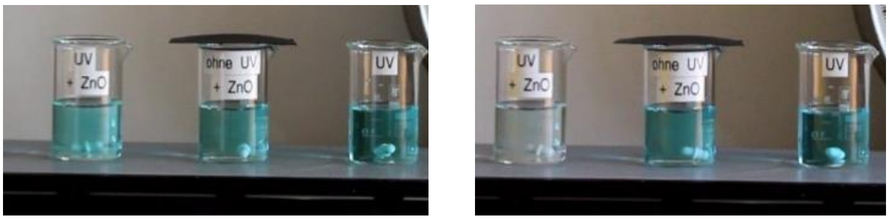


Figure 7: *Photocatalysis of a green malachite solution with UV-light, UV-light and zinc oxide nanoparticles and without any of them in comparison*

The decolourization is based on the degradation of the green malachite molecules by radicals that are produced by the irradiation of zinc oxide nanoparticles with ultraviolet light. A simplified process is shown in the following diagram [8].

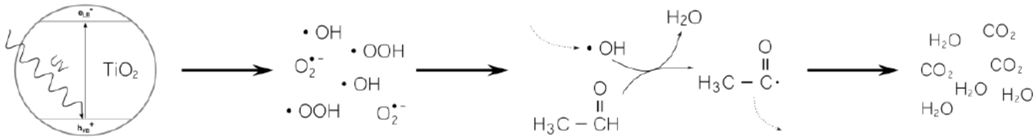


Figure 8: *Diagram showing a simplified process of the photocatalysis*

The explanation of this process is the goal of the tasks in this unit. First of all, the nanoparticle origin of the radicals will be explained. For this, the diagram from Unit 2 (Figure 5) will be used and extended. In the study book students also receive an information text explaining the phenomenon of the electron-hole pair. After the excitation process and an explanation model for it have been established, the students learn more about radicals in another information text. Their first task is to formulate a chemical equation for the reaction of either the electron or the hole of the electron-hole pair with one of the surrounding molecules. From these reactions, students deduce the reason for the decolourization of the solution. Furthermore, the students work out why this is called photocatalysis and from this gain a deeper understanding of the processes that underlie it. Finally, the use of the photocatalytic property of zinc oxide nanoparticles for photocatalytic surfaces is shown. Knowing this, students develop more possibilities to use this property. An example here would be the degradation of organic residues such as Bisphenol A in drinking water [8].

5. Unit 4 - „nano": Risks versus Potentials

The fourth unit focuses on the potential in comparison to the risks of nanotechnology. For this, another model experiment is conducted. In this experiment, the students put a few pieces of onion in a zinc oxide nanoparticle solution. After a few minutes, the small pieces are washed and irradiated with ultraviolet light. Here, it can be observed that the zinc oxide particles diffuse through the skin of the onion since the small pieces emit fluorescence from within. This experiment can raise awareness of the possibility that zinc oxide nanoparticles also interact with human cells. This is especially important because these particles are frequently used in sun blockers. In addition, the students are confronted with recent studies concerning this topic. Here, their task is to review the facts and to form an opinion on whether or not it is risky to use these particles in sun blockers. In the end, the legal regulations for this problem will also be presented.
For the second part of this unit, the students complete a WebQuest [9] on four other nanomaterials: titan dioxide, silver and silica nanoparticles as well as carbon nanotubes. This will be done in four groups, each focussing on a different nanoparticle. All have to work on a task concerning the

evaluation of risks in comparison to the potential of the respective nano component. The results will be presented in a presentation in class.

6. Realization of the Unit and Outlook

The unit has been conducted in two different classes in secondary schools. Reactions of teachers and students as well as an evaluation have shown that the topic and the study book were much appreciated. Many of them approved the unit, seemed to enjoy working with the study book and considered it a nice alternative to the usual teaching methods. Though the topic „nano" appeared to be quite demanding, they welcomed the challenge. The teachers also rated the unit as refreshing since it brought new and interesting topics into school chemistry education which are also related to modern research. This suggests that there is an interest in this topic that has not yet been satisfied during the usual science lessons. Teachers emphasized the relevance of the topic and that it refers to many educational standards of the regular curriculum. Thus it seems to be a worthwhile task to bring the topic into schools and to develop new teaching concepts concerning „nano".

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