irresistible

The Catalytic Properties of Nanomaterials

Teachers Guide

Responsible Research and Innovation www.irresistible-project.eu

Colophon

IRRESISTIBLE is a project on teacher training, combining formal and informal learning focused on Responsible Research and Innovation. It is a coordination and support action under FP7-SCIENCE-IN-SOCIETY-2013-1, ACTOVITY 5.2.2. Young people and science: Topic SiS.2013.2.2.1-1 Raising youth awareness to Responsible Research and Innovation through Inquiry Based Science Education. The project IRRESISTIBLE is funded by the EU as FP-7 project number 612367

www.irresistitle-project.eu
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General description

The importance of responsible research and innovation is discussed in the context of scientist's profile, research team building and various catalytic reactions, taking place at the surfaces of solids. Classroom experiments concerning adsorption and catalytic reactions (e.g. removal of dye from water, decomposition of hydrogen peroxide) are designed and performed by the students to introduce basic concepts of surface processes, nanomaterials and catalysis. Selected catalytic processes, both currently used or being developed (e.g. ammonia synthesis, purification of car exhaust gases) are brought to the stage, explored and analysed in order to assess the benefits and risks they pose to the environment and society. The issues were developed in the form of various exercises for students, largely based on the students' independent inquiry, both guided and open.

The teacher may implement the module in whole or select its elements only, depending on the students' advancement in chemistry and conducting experiments, time capabilities and compliance with the core curriculum.

Target group (in Poland): Lower secondary schools – students' projects
Upper secondary schools – afternoon school activities
duration of the module – 12-13 meetings (full version which can be cut/shortened)
science domain – chemistry

The module starts with a sequence of a general, introductory class, comprising both discussions and experiments as well as explanations concerning the Nature of Science (NoS) and planning and conducting school experiments (Figure 1).
Introduction to NoS & IBSE (Inquiry Based Science Education) may be omitted in those countries where the Nature of Science related topics are learned in advance or as a separate school subject, the students have extensive experience in planning and carrying out experiments and teachers are familiar with IBSE.
The meeting with scientists will support learning of NoS and develop/deepen students' understanding of some RRI issues.In the case of schools located in rural areas (far from research institutes), it can be realized in the form of a tele (video)conference (e.g. on Skype). It can also be limited to the tasks/exercises which are proposed in this module to be performed in groups of student on-site at school.
Then the workshops in the museum are conducted, so that by learning chemistry during subsequent stages the students can already plan/make up proposals for interactive exhibits. The substantive core of the module includes the classes on catalysis and photocatalysis. In junior grades, the teacher can accomplish the first part introducing the context and basic concepts of catalysis, while in senior grades the teacher may skip the basics and discuss the

method of preparing and examining their own catalysts, or focus on photocatalysis only (Figure 2) with the students.

In the final stage, constructing the exhibits and preparing the exhibition will take place.

During the implementation of the paths, <u>two organised visits outside of school</u> are planned:

a) at the university Chemistry Department/research institute. The visit consists of two parts:

- **a presentation of research conducted there (preferably related in substantive terms to the topic of the module i.e. the use of nanomaterials in catalysis, car fuel, air pollutions, chemical fertilisers), a presentation of the composition and work of the research team etc.**
- **discussions with scientists on various aspects of RRI based on the group work of students with specially prepared worksheets (questions about opinions)**

Later on the possibility of the performance of additional research, such as e.g. catalysts prepared by the students using the equipment available at the university can be organised.

b) in a science museum. The visit consists of three parts:

- **visiting the interactive exhibition**
- **assessment of the exhibits**
- **workshops on the construction of exhibits and exhibitions**

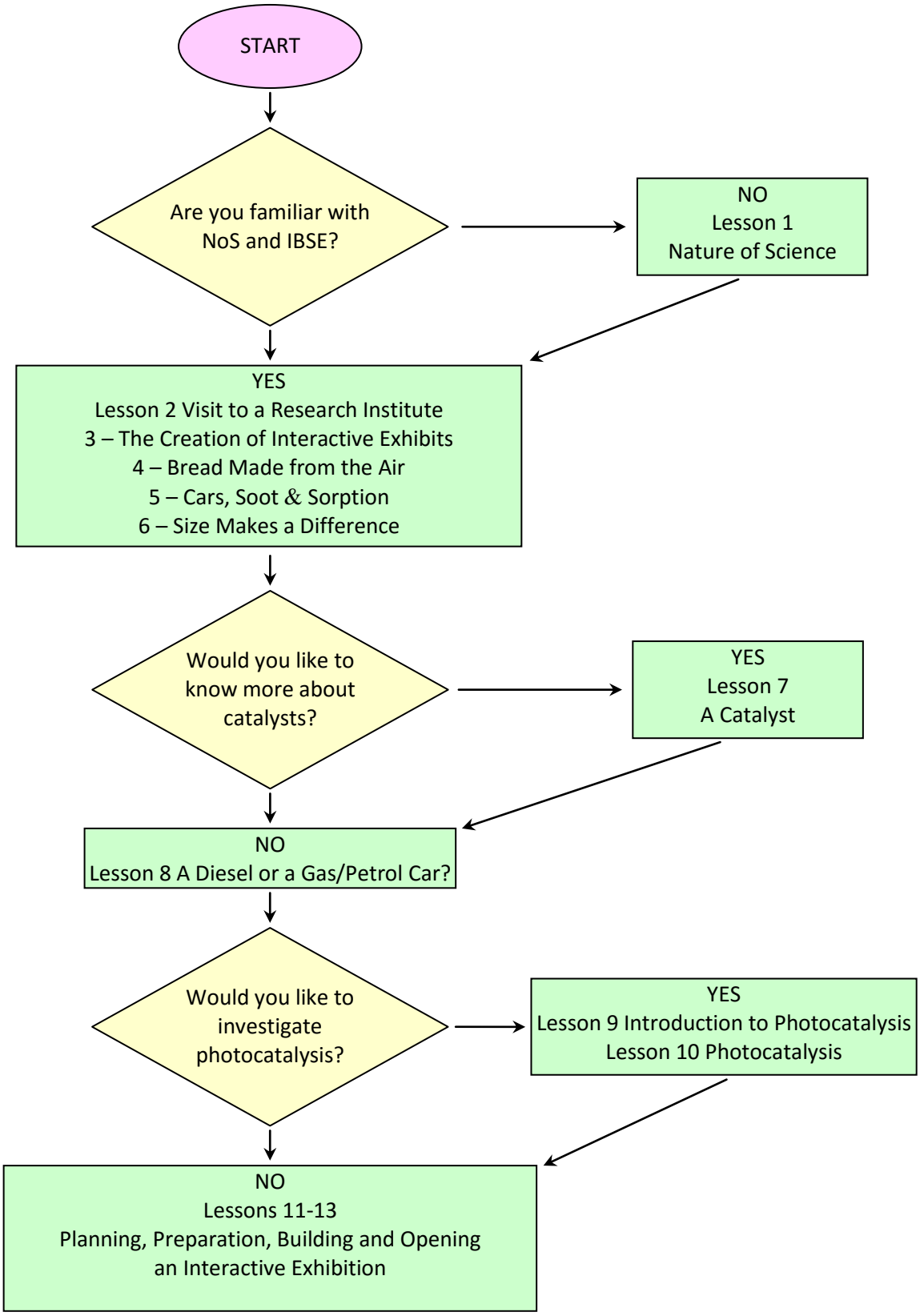

Figure 1: Possible pathways

PREREQUISITES

The module is prepared for students who have basic knowledge in the field of chemistry, and who are particularly acquainted with the following concepts and processes:

- **physical and chemical properties of substances,**
- **air composition,**
- **structure and properties of oxides, acids, hydroxides and salts (as well as obtaining salt in precipitation reactions),**
- **reaction rate,**
- **solutions (including concentrations),**
- **types of radiation (including visible and UV light),**
- **simple organic compounds and their properties (hydrocarbons, glycerine, detergents).**

LEARNING GOALS OF THE MODULE:

- **NoS – students can characterise the scientific method of investigation, enumerate the steps of inquiry/research,**
- **RRI – in the environmental context, students are able to explain the need of: a "chemists' code of conduct", which includes ethical aspects of research and innovation, choice of research topics based on societal needs, open access to results, equal opportunities for men and women, involvement of various societal actors (including civil society) in the RRI process, governance of research and innovations, as well as - science education for all,**
- **discuss the advantages and disadvantages of covering surfaces with nanoparticles,**
- **recognise the advantages and problems of using an automotive catalytic converter,**
- **IBSE – students are able to: make observations, ask questions, formulate a hypothesis, plan and perform an experiment (collect and analyse data/results), draw conclusions, communicate the results, work in groups,**
- **Chemistry – students are able to:**
    - **explain what the phenomena of sorption and adsorption consist of, what a catalyst is, what soot is and what carbon structures it is composed of,**
    - **discuss the role of a catalyst in chemical reactions and industrial processes,**
    - **suggest how to obtain large specific surface of a material/catalyst,**
    - **characterise a catalyst in terms of its most useful features: activity, stability, selectivity, preparation process, the possibility of recycling, active surface,**
    - **plan and carry out demonstration experiments presenting the adsorption phenomenon and examining the catalytic activity of nanomaterials,**
    - **propose a method of measuring the reaction rate and its mathematical description,**
    - **plan and carry out demonstration experiments illustrating the photocatalysis phenomenon,**
    - **discuss selected properties of TiO_2.**

RESPONSIBLE RESEARCH AND INNOVATION

References to various aspects of Responsible Research and Innovation occur in 3 forms:

a) **Context – related to the functioning of society (hunger, health) and the environment (air, earth and water pollution), including: 'Volkswagen – the 'dieselgate' scandal discussion and the final SWOT analysis 'nanomaterials in the environment';**
b) **Separate classes at school on the image of a researcher and the method of conducting research (as a prelude to a visit to a research institution);**
c) **Getting acquainted with the work of research teams (workshops at the university) – that includes:**
   - **the role of all societal actors (researchers, industry, policymakers and civil society) in the RRI process,**
   - **the transparency and accessibility of research and innovation –in the form of a presentation of recent research findings by scientific co-workers and a discussion,**
   - **ethical aspects and the governance of research and innovation.**

WEB 2.0 TOOLS& APPS

Application of Web 2.0 tools& appsis highly recommended – both in the form of the use of already existing materials (published/shared in the Internet on the Wikipedia type platforms), as well as, for example, working in Facebook groups, where students can exchange documents, opinions, invitations, remarks, reflections etc. Some suggestions are presented in table 1.

table 1

Proposed ICT tools

Purpose	Presentations	Pictures, films	Map concepts	Comics
Software	Prezi Prezior Glogster	Lapse It One Second Everyday Animato	Mindomo Cmap	Pixton Write Comics

The module consists of a set of lessons/projects (afternoon/out of school activities) scenarios. Each scenario includes:

- **a list of learning outcomes,**

- **descriptions of students and teacher activities/actions: discussions, experiments, tasks, group work, presentations, links, homework etc. Activities are indicated by icons (Table 2),**
- **evaluation tools.**

table 2

Icons used in the materials for teachers and students

Assignment	Computer	Experiment	Info	Sources	Summary
Table	Time	Weblink	Activity	Activity Sheet	Discussion
Group work	Laboratory safety	Note	Presentation	Reference to materials for students	Reference to exhibition

Separated materials for students include: information, worksheets, additional literature etc. Some of those scenarios even include a detailed presentation of students-teacher conversations. It is not expected that these examples will be copied in reality! They are just the suggestions of a pathway on which a particular topic can be developed.
Each scenario is based on the 5E structure typical for IBSE (Inquiry Based Science Education): Engage, Explore, Explain, Extend, Evaluate.

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1

Nature of Science

Lesson No.1

Nature of Science (NoS)

Learning objectives:

- **Making the students familiar with a scientific method and its characteristics;**
- **Discussing the process of science development;**
- **Developing the skill of using social media, selecting them and critical evaluation of information;**
- **Developing the skill of conducting a discussion and drawing conclusions;**
- **Making the students familiar with IBSE; developing research skills.**

Learning outcomes:

A student is able to:

- **list the stages of a research process;**
- **characterise a scientific method.**

Time: 45 minutes

1. Engage

1.1 Brief preliminary discussion with the students: ‘Does science develop by coincidence?’

1.2 Matching exercise

The persons in the class are divided into groups of a maximum of 4 persons. Each group receives a worksheet – a table to mark the matches: a scientist – a coincidence associated with him/her, owing to which the scientist developed his/her theories.
Correct answers: 1F, 2C, 3D, 4B, 5A, 6E, 7G.

2. Explore

2.1 Debate ‘How is science created?’ (introducing cognitive dissonance)

- students receive cards presenting the views published online on the forum of the gazeta.pl portal ‘The role of coincidence in the development of Pure Science’ http://forum.gazeta.pl/forum/w,32,115969533,115982012,Re_Rola_przypadku_w_rozwoju_Czystej_Nauki_.html
- students, alternately, present two opposing points of view (in their own words, based on the cards received)

F – for, A – against

Student F2 – Isaac [Newton], by accident, becomes the owner of a piece of edged glass, and an apple falls on his head – we all know the effect.

Student A2 – A long time before Newton, Zacharias Janssen, Jacob Metius, Galileo and Kepler used to deal with edging. Optics was then the greatest scientific achievement, so it would be strange if such a scientist had not encountered it. Again – no coincidence.

Student A3–Without the help of an apple, but knowing the Kepler's law and Hook's ideas (of replacing the 'spiritual influence' through which the Sun moves the planets, and the Earth – the Moon, by a physical force), and the concept of inertia, introduced by Descartes, Newton needed only one tool: the differential calculus. When he invented the calculus, the development of his theory of gravity was just a matter of time. Once again, nothing happened by coincidence.

Student F4 – ‘the Curie couple discovered radioactivity accidentally, keeping a photo film in a drawer together with an ore of uranium – with a memorable effect.’

Student A4– ‘In fact, radioactivity was discovered by Becquerel, of whom Maria Skłodowska-Curie was a PhD student – so there was nothing coincidental in her research. Becquerel studied phosphorescence, and he would have probably been another of the scientists studying it unsuccessfully for 40 years (since, to explain it, you need to know quantum mechanics), unless he had used in his research on uranium ore. So the coincidence actually occurred in that case: by accident, so much time had passed. If not for a coincidence, radioactivity could have been discovered much earlier.

Student A5– ‘Although there are coincidences in science, their role is limited to shifting a discovery a few years forward or backward in time.’

Student A6– ‘The basis of science is experimental verification, which consists in the fact that based on the theory, the result of a still non-conducted experiment is predicted, and then the experiment is carried out and its results are compared with the expectations.’

Student A7– ‘Whether new scientific ideas are interesting and ground-breaking or not is determined by the opinion of the **community**, i.e. *peer review*

- an opportunity to express other students’ own opinions
- discussion summary

2.2 Posing a question – Is science immutable? Will the things that we learn at school today (theories, definitions, laws) apply until we get old?

2.3 Discussion distinguishing between the following concepts: definition, theory, hypothesis, law, model.

2.4 Matching exercise (2) – connect the researchers and the views presented by them using lines; state whether the opinions are relevant to-day.

Note:
The selection of names depends on the teacher's creativity, the level/scope of knowledge possessed by the students in a given class etc. It is important to include among them the persons whose views are out of date now, and not to forget about female scientists.

- Summarising talk

3.Explain

3.1 Group work – students develop the scheme of conduct in a scientific method – prepare a poster by putting the steps of the research process in a proper sequence.

Teaching note:
It is necessary to prepare a double number of cards with the names of the stages of the research process for each group; the scheme should have a circular shape, it should not be a straight line.

Presentation of the students' posters to the rest of the class compared to the definition of the scientific method (e.g. https://en.wikipedia.org/wiki/Scientific_method) and discussion.

Stacking cards which describe the steps of a research process in a proper sequence could be an example of an interactive exhibit.

4. Elaborate

4.1 Conducting a simple student experiment in groups using the IBSE convention, with the identification of various stages by the students (from formulating the problem, through planning, defining variables, to the presentation and critical analysis of the results and conclusions), for example studying the impact of various factors on the stability of colloids or emulsions.

5. Evaluate

Jumbled phrases – task: 'select the elements typical for a scientific method.'

single trial	basing the conclusions on the inner scientist's conviction	comparing the results
lack of control over the tests' conditions	analysis of the current state of knowledge on the topic	repeated attempts
non-falsified hypothesis	basing the conclusions on evidence (test results, observation)	maintaining constant values of controlled variables
hypothesis which can be disproved	presentation of results to the scientific community	

2

Visit to a Research Institute

Lesson No.2

Visit to a Research Institute

Learning objectives:

- **Making students familiar with the cutting-age science and the work of scientists;**
- **Developing awareness of gender inequalities between men and women.**

Learning outcomes:

A student is able to:

- **explain the need of: a 'chemists' code of conduct', which includes ethical aspects of research and innovation, choice of research topics based on societal needs, open access to results, equal opportunities for men and women, involvement of various societal actors (including civil society) in the RRI process, governance of research and innovations, as well as – science education for all.**

Time: 90 minutes

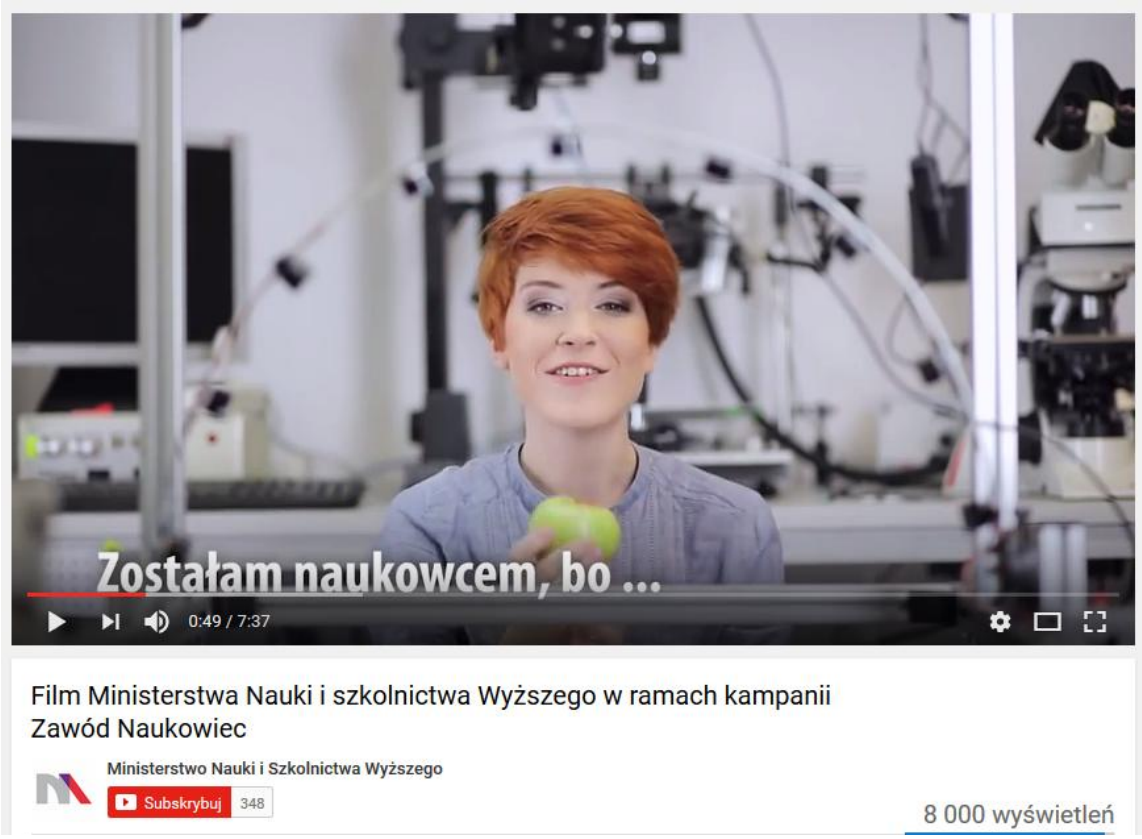
PREPARATORY CLASS

1. Engage

1.1 Presentation of a video

'Zawód naukowiec' – 'I became a scientist because ...'

http://youtu.be/ucekm94m5h0(Occupation: Scientist)



or similar about the work of scientists
e.g. 'A Day in the Life – Environmental Scientist'

https://www.youtube.com/watch?v=WKx-TrwlgG4

- students' reflections, developing a list of questions to scientists that emerged after watching the video e.g. To what extent does it reflect the reality? What qualities should a good scientist have? Where do the research topics originate from? Who funds research? Who evaluates research? Do scientists make mistakes?

2. Explore

Based on Fit for Gender Mainstreaming http://www.gendertoolbox.org;based on Fit for Gender Mainstreaming http://www.gendertoolbox.org

2.1 Group work–preparation of a collage presenting a research group (various roles and positions) in same-sex working groups:

- Materials: coloured newspapers and magazines, pictures, postcards, glue, scissors, wrapping paper, thick markers in various colours, adhesive tape;
- Objective: becoming aware of different approaches to the task in same-sex work teams, understanding the importance of a mixed (in terms of sex) composition of groups for the effectiveness of the actions taken;

- Task (boys and girls separately):

In same-sex groups, using the colourful newspapers available, old calendars, postcards, drawings and other materials, make a collage depicting the work and allocation of roles in a research (scientific, project) team composed of both women and men. Take into account the persons that: manage the work, conduct research, perform the calculations, present the results to grant giving organisations, present the results at a meeting with young people etc.

The preparation of a collage could be an interactive exhibit.

3. Exchange

Presentation of the collages to the rest of the group, exchange of opinions and discussion on:

a) The process of creating a collage (what were the first ideas that came to the students' minds? Did they change the allocation of roles according to sex later on? Did they refer to some personal experience e.g. parents are scientists, to a trip to a research laboratory, or to information from the mass media – films, Internet news, or internal convictions? Did the thing that they based their proposals on have a visible impact on those convictions? Was everyone in the group of a similar opinion? Why did they allocate such and not other roles to various sexes?);

b) Differences and common elements in the results of same-sex groups (Who performs what role? How many men and how many women are members of a research team?).

4. Extend

Based on Fit for Gender Mainstreaming http://www.gendertoolbox.org;based on Fit for Gender Mainstreaming http://www.gendertoolbox.org

4.1 A gender quiz

1. Considering the period from 1995 to 2007, how much has the share of women in the group of professors in Germany grown?
   a) from 15 to 30%
   b) from 8% to 15%
   c) from 30 to 40%
   d) from 40 to 60%

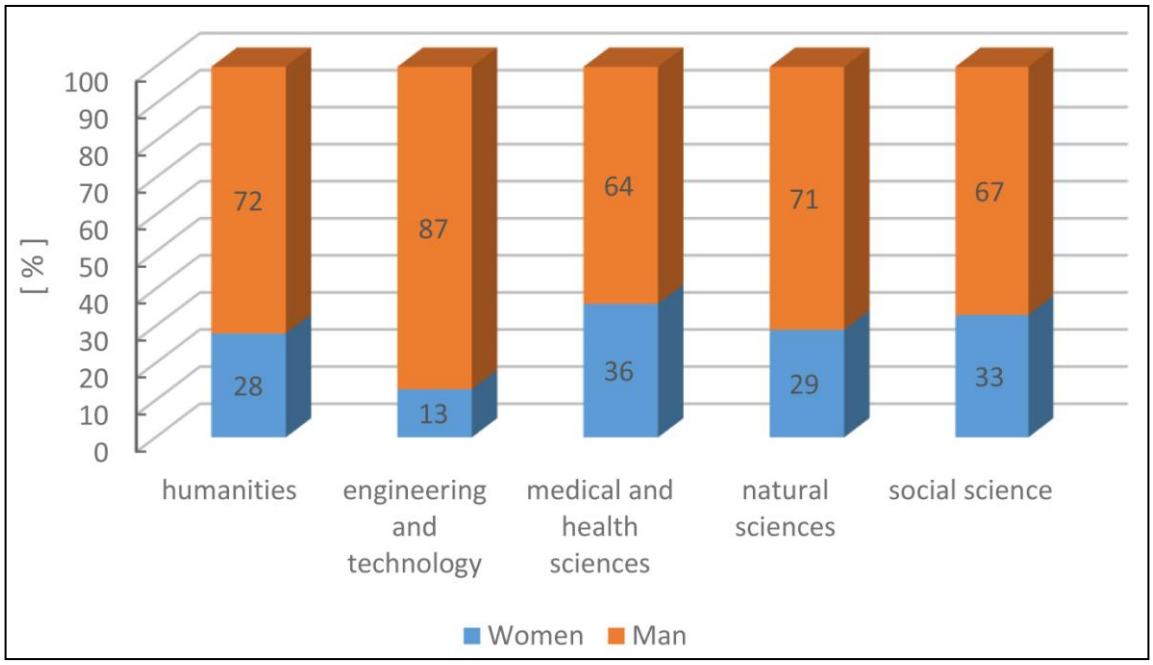


Figure 4.1: The titles of professors awarded in the year 2002 by the field of science and sex (%)
Source: calculations of the National Information Processing Institute
(www.uprp.pl/uprp/redir.jsp?place=GalleryStats&id=15882)

2. What is the share/ratio of women and men in the EU in the course of a scientific career?
   – Which sex is represented in the greatest number?

	Men (%) 1999-2003		**Women (%) 1999-2003**	
Students M<W	4846	52	54	
Graduates M<W	44	41	56	59
PhD students M>W	56	54	44	46
PhD studies graduates M>W	62	57	38	43
Young professors M>W	63	58	37	42
Senior professors M>>W	70	68	30	32
Highest positions M>>W	87	85	13	15

3. When was the first female President of the Supreme Court in Poland appointed?
   a) never
   b) in 2014
   c) in 2005
   d) in 1991

4. Based on the diagram below, name 6 fields of study most often chosen by girls (in Poland).

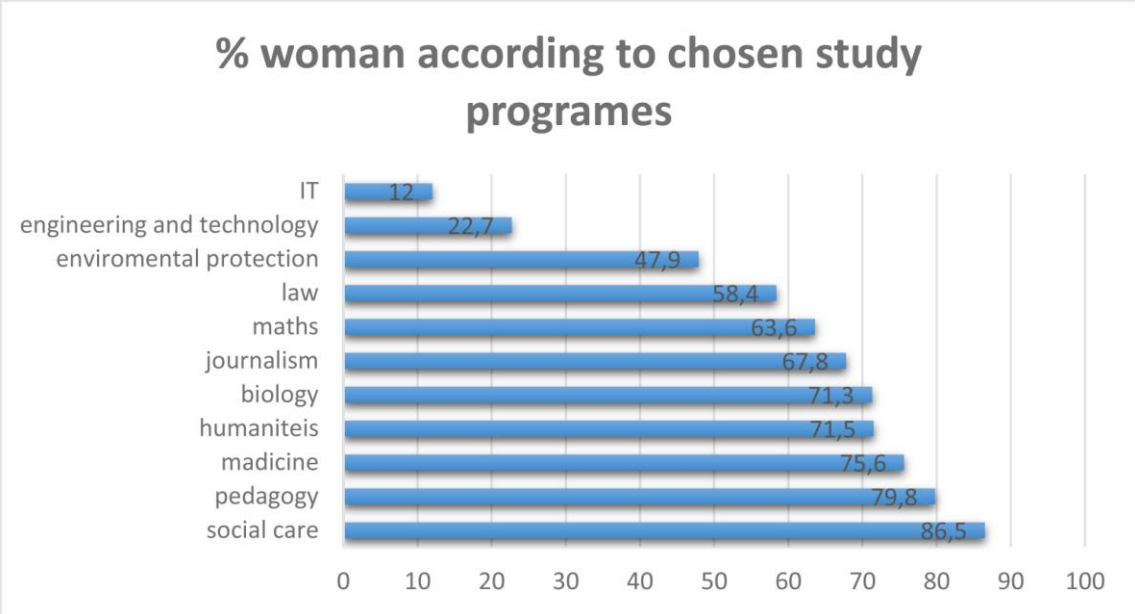


Figure 4.2: % woman according to chosen study programes (www.studentka.pl)

5. When was a woman appointed as the head of the CERN research centre for the first time?
   a) in 1995
   b) in 2005
   c) <u>in 2014</u>
   d) never

Meeting with scientists

<u>1. Engage</u>

Visit to scientific laboratories (in small groups), meetings with scientists who explain their work, simple measurements or presentations of instruments and results of research.

JU case:

a. Determination of Aunanoparticle size,
b. Investigation of oxidation of soot by Fe_2O_3 using a thermobalance,
c. Investigation of the catalytic reduction of NO using a mass spectrometer.

2. Explore & Exchange

Group work based on worksheets – each group discusses a different topic. Presentation of results of the group work.

3. Explain

Plenary discussion between students and scientists based on the completed worksheets.

3

The Creation of Interactive Exhibits

Lesson No.3

The Creation of Interactive Exhibits

Learning objectives:

- **To acquaint the students with the concept of an interactive exhibition and interactive exhibit;**
- **To develop the ability to work in a group and hold a discussion;**
- **To remind the students of the concept of RRI and its dimensions;**
- **To raise awareness of the importance of informal education.**

Learning outcomes:

A student is able to:

- **describe the characteristics of an interactive exhibit;**
- **enumerate various ways of interacting with the audience at an exhibition.**

Time: 90 minutes + a visit to the exhibition (or 140 minutes)

1. Engage

A visit to an interactive exhibition.

1.1 Various examples of different ways of involving the viewer in the experiment (manual and mental involvement) are shown.

1.2 Students evaluate the selected exhibits by filling in the evaluation form.

Teaching note:
It is better to point out the exhibit for evaluation than leave it to the student's choices because students most often chose only easy and funny exhibits and, because of that, tend to learn less.

60 min.

If the workshop is not held at an exhibition but at the school

1.1 A film presenting an interactive exhibition
e.g. https://www.youtube.com/watch?v=5k_6QpUbPlc

Teaching note:
It is better to use a movie from the science center which may be known to your students.

1.2 Discussion about interactive exhibitions

What is an interactive exhibition? Where can we find such an exhibition - in a Museum, in a Science Centre? What is the difference between a Museum and a Science Centre? Has any of the participants been to a Science Centre? What exhibits do they remember from the visit? What exhibits did they like best? And what exhibits taught them the most? What must be the necessary features of an exhibit to call it an interactive one? What did the interaction with the exhibit consist of? Did the students try out the exhibits that required cooperation with other viewers?

30 min.

1.3 The participants work in pairs

Materials: strings, wires, plasticine, adhesive tapes, straws, skewers, screw cups, CDs, scissors, clips, paper clips, balloons
A task: prepare within 5 minutes an experiment using the balloon.
The experiments are presented to the public (e.g. Sitting on the balloon, driving a skewer through a balloon, blowing between two hanging balloons).

2. Explore

2.1 Group work

Each group receives a different interactive exhibit (e.g. memory, two dice, nanosilver book). Students first perform an experiment using their exhibit, and then analyse and evaluate the exhibits presented. They can also prepare some new instructions for using their exhibit. Then, each group presents their exhibit to the rest, together with the conclusions from the discussion.

Memory – below a pair of identical images there are two captions located – together they form a sentence on how the application of nanotechnology may change our world. After uncovering two identical images, the presented problem should be discussed.

Two dice – on one dice 6 nanotechnology methods are described that may be used in environmental protection. On the second dice, there are 6 dimensions of RRI listed. After throwing both dice, the students in the group should find a possible combination of those two descriptions.

Figure 3.1: Two Dices – Nanotechnology in environmental protection (Photo: Elżbieta Serafin)

The Dice Sides – NANOTECHNOLOGY IN ENVIRONMENTAL PROTECTION

Dice I (RRI)

Involvement
Joint participation of scientists, politicians, and the representatives of industry and civil society in the process of analysing the social, economic and ethical meaning of research and innovation.

Gender equality
Releasing the full potential of society. Women often are less involved in the research and innovation process than men.

Education in the field of science and natural science
Creative education supporting the future needs of society. Preparing both future scientists and other citizens to assume the responsibility for research and innovation.

Ethics
Scientific research and innovation should respect the fundamental rights and the highest ethical standards in order to make the social importance and acceptability of the results of research and innovation increase.

Unlimited access
Free and unpaid access to the results and data of publicly funded research.

Management
The responsibility of policy makers for creating harmonious models of research and innovation. It is the basis for the development of other dimensions of RRI.

DICE II (Nanotechnology in environmental protection)

Nanofilters
Membranes that are used to filter water. They allow for the purification of water from organic compounds and ions. They are also used to soften water. Filtration is carried out at a lower pressure than when using conventional methods, which means energy savings.

Aerogels
Sponges made of aerogel having hydrophobic properties may be used to clean the sea surface from oil slicks. A sponge dropped onto the slick will be able to absorb the oil the mass of which is several times greater than that of the spongeand, after cleaning, the sponges can be reused.

Nanosilver
A filter made of cotton coated with a layer of carbon nanotubes and silver nanowires and connected to a power source may effectively purify water from bacteria. The bacteria passing through that barrier are killed, but no water flow is prevented.

Biodegradable plastic
The use of nanoparticles in biopolymers will lead to the obtaining of material with good mechanical properties, which will be also suitable for composting.

Dyes removing nitrogen oxides
Silicone-based dyes contain nanoparticles of titanium dioxide and calcium carbonate with the sizes of 30 nm. The base is porous enough to make it possible for nitrogen oxides to penetrate it, and the particles then adhere to the titanium dioxide ones. The particles absorb ultraviolet radiation from sunlight and use this energy to convert nitrogen oxides to nitric acid

Self-cleaning glass
Glass covered on the outside with a titanium oxide coating, the photocatalytic properties of which result in the fact that under the impact of UV radiation organic impurities are decomposed, and hydrophilic properties of the coating make the

impurities flush away during rainfall. Hydrophilicity also results in the fact that water flows down the surface in a uniform layer instead of forming trickles or individual drops. Windowpanes made of such glass need to be washed or cleaned much less often.

Nanosilver Book

A small book presenting the medical application of nanosilver. But in its further content open questions to a viewer are found. Those questions should be discussed and the conclusions should be noted down.

A brief **discussion**– Can we call those exhibits interactive? How are they different from the ones that you have seen in the Science Centre (at the exhibition).

Figure 3.2: Nanosilver book (Photo: Beata Sobocińska)

3. Elaborate

3.1 **Brainstorming** – what other interactive exhibits of that type can you come up with? **20 min.**

Teaching note:
It should be mentioned that the documentation of the students' participation in the project may also become an exhibit – the results of the students' research, presentation of a research process by the students or scientists, interviews and street surveys carried out etc.

4. Explain

4.1 Teacher/museum staff **presentation** on various ways of understanding interactivity, as well as the examples of interactive exhibits, both physical ones and the ones provoking discussion: poster, book, game, video.

5. Extend

5.1 **A discussion** on how a viewer may leave his/her 'imprint' at the exhibition; how to register his/her choices and opinions.

Educational comments:
It should be mentioned that students build exhibits to communicate science to visitors. Students, as the creator of the exhibits, exchange roles with teachers because they explain their ideas to visitors. It is a kind of informal education. The school exhibition plays an important role in educating the society.

Closing the workshop

4

Bread Made from the Air

Lesson No.4

Bread Made from the Air

Learning objectives:

- **Making students familiar with the concept of sustainable development, a catalyst;**
- **Developing their ability to work in a group, conduct a discussion, explore the literature, select the information, plan and perform an experiment, formulate observations and draw conclusions, and present and interpret the data.**

Learning outcomes:

A student is able to:

- **explain the role of a catalyst in chemical and industrial processes;**
- **characterise the scientific method of investigation, enumerate the steps of inquiry/research;**
- **plan a simple experiment, identify the dependent, independent and controlled variables.**

Time: 90 minutes

1. Engage (Introduction):

1.1 Presentation of a short film/video clip showing the problems of modern civilisation e.g. ‘What Are The World's Biggest Problems?’ https://www.youtube.com/watch?v=YY9nxG2ZQ7

1.2 Sustainable development –group work using the ‘carpet of ideas’ technique

The teacher asks: In what kind of world would you like to live? What is necessary to live at an appropriate level? Think about this not only from the perspective of a developed European country in which you live, but also from the perspective of the rest of the world.
The students, in small groups, list their ideas on post-it notes, then read the ideas and stick the notes on the board (e.g. the abundance of goods, including food and water, health, education, work, security, leisure, developed economy, unspoiled nature, freedom etc.), possibly in the vicinity of the ones that are already hanging there and contain the texts focusing on similar issues. A discussion is then held in front of the entire class on the

possibility of grouping the statements. The optimal solution is to distinguish 3 to 5 groups – the dimensions of sustainable development (Fig. 4.1):

Figure 4.1: Sustainable Development (Author: Dmitry / Fotolia)

Figure 4.2: Sustainable Development Goals
(http://www.un.org/sustainabledevelopment/sustainable-development-goals/)

2. Explore

2.1 Food for humanity – a conversation based on the watched film and previously gained knowledge, including that obtained in biology lessons

Teaching note (educational comments)
– if the students cannot answer the questions based on their prior knowledge gained at school at the previous stages of education, during the lessons of other subjects or general/common knowledge, the teacher asks a question in a different form or provides leading questions, or reminds the students where (at school, in the media etc.) they might have discussed a given topic, and from various students' suggestions s/he chooses those proposals (not necessarily the 'correct' ones) that will used by him/her for further discussion

Teacher (T): What do you think is the cause of problems regarding an appropriate amount of food in the world?
Students (S) –potential responses: lack of water, infertile soil, plant and animal diseases, harsh climatic conditions (temperature, sunlight)
T: What is necessary for plants to live?
S: Water and biophile elements: N, P, C, H ...
T: Where is there a lot of nitrogen?
S: In the air.
T: Can plants take nitrogen from the air?
S: No, only legumes can do it.
T: If they cannot use nitrogen in the form of an element, then maybe they can do it when it is in chemical compounds? What nitrogen compounds do you know?
S: Nitrates, ammonia, amines, amino acids, proteins …
T: Which of these compounds are present in nature in an easily available form?
S: Nitrates in the form of minerals – saltpetre.
T: Which saltpetre is relatively the richest in nitrogen?
S: Ammonium nitrate.
T: What do you think - would it be possible to use the nitrogen present in the air for the synthesis of ammonia needed for the production of ammonium nitrate?

The students form hypotheses.

2.2 Presentation of the first part of the slides: 'Bread Made from the Air'

2.3 Discussion – verification of hypotheses

T: On the Haber-Bosch reaction: drawing the attention to the fact that to split the nitrogen-nitrogen bonds in a nitrogen molecule we need a lot of energy and, simultaneously, the molecules involved in the reaction should be properly arranged in space in relation to each other (appropriately oriented towards each other).

T: As you can see, it is difficult; we need a factor that will facilitate such a reaction.

Teaching note:
Depending on whether the students are already familiar with the concept of a catalyst or not, further discussion may be held in various ways.

If they ARE FAMILIAR with it – the continuation of the presentation of information on the use of catalysts, which helps to solve both above-listed problems of making it clear to the students that every other nitrogen atom in our body has passed through the Haber-Bosch reactor.

If the students ARE NOT FAMILIAR with the concept of a catalyst:
T: *Imagine the situations in which, in order to complete a task, you first have to overcome a barrier. What were the situations? Did you find any solution?* – a **discussion** with students e.g. to be able to roll a heavy object down the slope easily, first we need to move it, overcoming the friction force; when there is a traffic jam on the city streets; or the drive was too steep for a bike - you need to choose a different way.
T: And how about relationships between people?
If two people commute to school using the same bus, after a while they may get to know each other, but it may take years to happen. When they meet a common friend, it is very easy.

2.4 Exercise

T: Check the expiration date on the packaging of hydrogen peroxide. And what is the expiration date of salicylic spirit used for disinfecting wounds? What do you think? Why are there differences?

S: Those substances have different durability i.e. one enters into chemical reactions more easily than the other

2.5 Introduction of inquiry principles in a context of catalysis

2.5.1 Presentation of the catalytic decomposition of hydrogen peroxide with the use of potassium iodide in the presence of detergent.

(https://www.youtube.com/watch?v=NenWLNC0GaE
https://www.youtube.com/watch?v=UTfMrx7275w)

2.5.2 Planning of an experiment

T: What would you like to explore in this reaction?

S: What other substances act in a similar way i.e. can accelerate the decomposition of hydrogen peroxide?

T: It will be our research question. What are your ideas or hypotheses to test?

S: ... other salts, organic compounds ... have a similar effect as PbI_2

T: We will call the tested substances ‘independent variables’. What do you want to observe?

S: ... foam head height

T: It will be our dependent variable, because we test its dependence on the substance added to hydrogen peroxide

T: How are you going to note down the results?

S: ... for example, in a table...

T: Should any conditions remain unchanged so that we could compare the obtained results?

S: The physical state of the added substance, volume and concentration of salts if they are in solution, the volume and expiration date of the hydrogen peroxide, the temperature at which the experiment is carried out, the method of measuring the foam head height (the same person is observing while holding a measuring cylinder so that the foam level was at eye level) ....

T: These parameters are called controlled variables.

T: Do you think that one measurement of a substance is enough? And what if the person reading the foam head height makes a mistake?

S: ... we will need to repeat the experiment.

T: Plan the course of the experiment in detail, write it down on the enclosed worksheet and give me the plans back; then do the experiment, collect the data, demonstrate your results to the rest of the class and compare them with the results of other groups.

2.5.3 Conducting an experiment

2.5.4 Data analysis, drawing and presentation of conclusions

T: Have you obtained an answer for your research question?

3. Explain

3.1 Introduction of a definition of a catalyst

3.2 Continuation of the presentation 'Bread Made from the Air'

– therefore, it is best to do this using a catalyst, making it clear to the students that every other nitrogen atom in our body has passed through the Haber-Bosch reactor.

4. Extend

4.1 Presentation of an anecdote:

The wife of Professor Haber was not pleased that her husband was spending so much time at work. One day she decided to visit him unannounced. Professor Haber, delighted, was showing her around the hall in which the research on finding a suitable catalyst for the synthesis of ammonia was being conducted. His wife, even more concerned about his enthusiasm associated with work, and a bit angry, took off a brooch received from her husband and dropped it into the reaction vessel that she was standing next to. It was a platinum brooch ...

T: What do you think? Could the throwing of the brooch change the speed of the reaction?

Teaching note:
The following discussion will proceed in various ways depending on whether there was a catalyst in a solid state used in the students' experiment

If not – the teacher asks: Can a catalyst be a solid?

4.2 Introducing the concept of homogeneous and heterogeneous catalysis.

T: Does it matter what a solid looks like? For example, how fragmented it is? (a reference to the previous lesson on the factors affecting the dissolution rate) ...
– this will be discussed during the next classes

4.3 Work with literature/Internet on ethical problems in a researcher's life

Figure 4.3: Fritz Haber (Author: rook76 / Fotolia)

T: Find in the available sources the information on the biography and scientific work of F. Haber.

or

T: Read the provided information (good/positive side of Haber's work)

- https://en.wikipedia.org/wiki/Fritz_Haber up to a part "Nobel prize")

and answer the question "What do you/did you think about Fritz Haber based on it?"

The analysis of the other part of the text (negative side

- https://en.wikipedia.org/wiki/Fritz_Haber chapters "World War I" and "Between World Wars" and about his wife http://behindnmrlines.blogspot.com/2013/02/inspirational-women-chemistry-edition.html), and the discussion on how the new information changed the students' opinion on F. Haber

4.5 The discussion

On ethical considerations of scientific research, factors affecting the taking up of such and not other research topics (funds, power, fame, pressure...), responsibility of not only the scientists but, most of all, the persons commissioning the research.

5. Evaluate

Students answer some questions[1]

1. Heterogeneous catalysis is defined as a phenomenon where:

A. Catalyst and reagents are in gas phase
B. Catalyst and reagents are in liquid phase
C. Catalyst and reagents are in solid phase
D. Catalyst and reagents are in various phases

2. What effect does a catalyst have on a reaction?

A. It increases the rate
B. It increases the yield
C. It increases the heat of reaction
D. It increases the activation energy

3. Which pair of reactants is used to industrially synthesise ammonia?

A. H_2O and NH_4^+
B. H_2 and N_2
C. H_2O and N_2
D. H_2 and NO_2

At the end of the lesson a teacher might ask students:

What have you learned by conducting experiments at today's meeting?
Where in everyday life can you observe a catalytic phenomenon?

[1] P. Boroń work (JU)

table 4.1

Example of a student's knowledge self-assessment after the lesson no. 4: *Bread Made from the Air*

Topic: *Bread Made from the Air*	With substantial help from the teacher	With help from the teacher	Independently
1. I can define a catalyst			
2. I can explain the role of a catalyst in chemical and industrial processes			
3. I can plan a simple experiment with a catalyst			
4. I can identify dependent, independent and controlled variables in an experiment scheduled by myself			
6. I can specify three dimensions of sustainable development			

5

Cars, Soot & Sorption

Lesson No.5

Cars, Soot & Sorption

Learning objectives:

- **Making the students familiar with the concept of absorption, adsorption, specific surface area;**
- **Revising the concept of colloidal solution, allotropic varieties of coal, combustion of hydrocarbons;**
- **Developing the ability to work in a group, conduct a discussion, explore the literature, select the information, plan and perform an experiment, formulate observations and draw conclusions, reason, generalise, present and interpret the data;**
- **Making the students aware of the dangers resulting from the presence of pollution in the air.**

Learning outcomes:

A student is able to:

- **explain what the phenomena of absorption and adsorption consist of,**
- **plan and carry out a demonstration experiment presenting the adsorption phenomenon,**
- **propose methods for reducing air pollution.**

Time: 90-120 minutes

1. Engage (Introduction)

1.1 **Presentation** of a YouTube video showing smoky cars
https://www.youtube.com/watch?v=QgkAvQfkfNM

and reading the news:

Diesel Exhaust and Cancer
http://www.cancer.org/cancer/cancercauses/othercarcinogens/pollution/diesel-exhaust-and-cancer
France Wants To Get Rid Of Diesel Fuel
http://www.businessinsider.com/r-france-to-rank-cars-for-pollution-wants-to-phase-out-diesel-fuel-2014-11?IR=T

1.2 **Discussion** on vehicles' exhaust fumes

T: What comes out of an exhaust pipe?
S: Smoke, exhaust fumes.
T: What kind of mixture is it?
S: It is a colloid (*if they know from the previous lessons*).

T: What is the solvent?
S: The air.
T: What are the solutes in the air in this case? –Try to recall from the lessons on hydrocarbons and energy sources.
S: CO_2, CO, CxHy, dust, NOx.
T: Why is the smoke black?
S: Because it contains carbon and soot.
T: Where does the soot in the exhaust fumes come from? Try to recall from the lessons on hydrocarbons.
S: From the incomplete combustion of hydrocarbons as the main component of petrol and diesel fuel.
T: And is the soot also created during the combustion of fossil coal? Why are the colours of the facades of tenement houses in Krakow so dark?
S: The soot - formed during the combustion of hard bituminous coal - settles on them.
T: Then, what is soot? – Try to define it or recall from the lessons on the allotropic varieties of carbon.
S: Deformed graphite crystals, resulting from the incomplete combustion of fossil fuels.
T: Not only … graphite crystals are the main components.
Presentation of soot definition
T: Do you know how big soot particles are?
S:...

1.3 **Presentation** of Fig. 5.1

–- Tell your students that they will see a drawing from a scientific publication showing the structure of soot. Ask students what they think may cause differences in the soot structures.

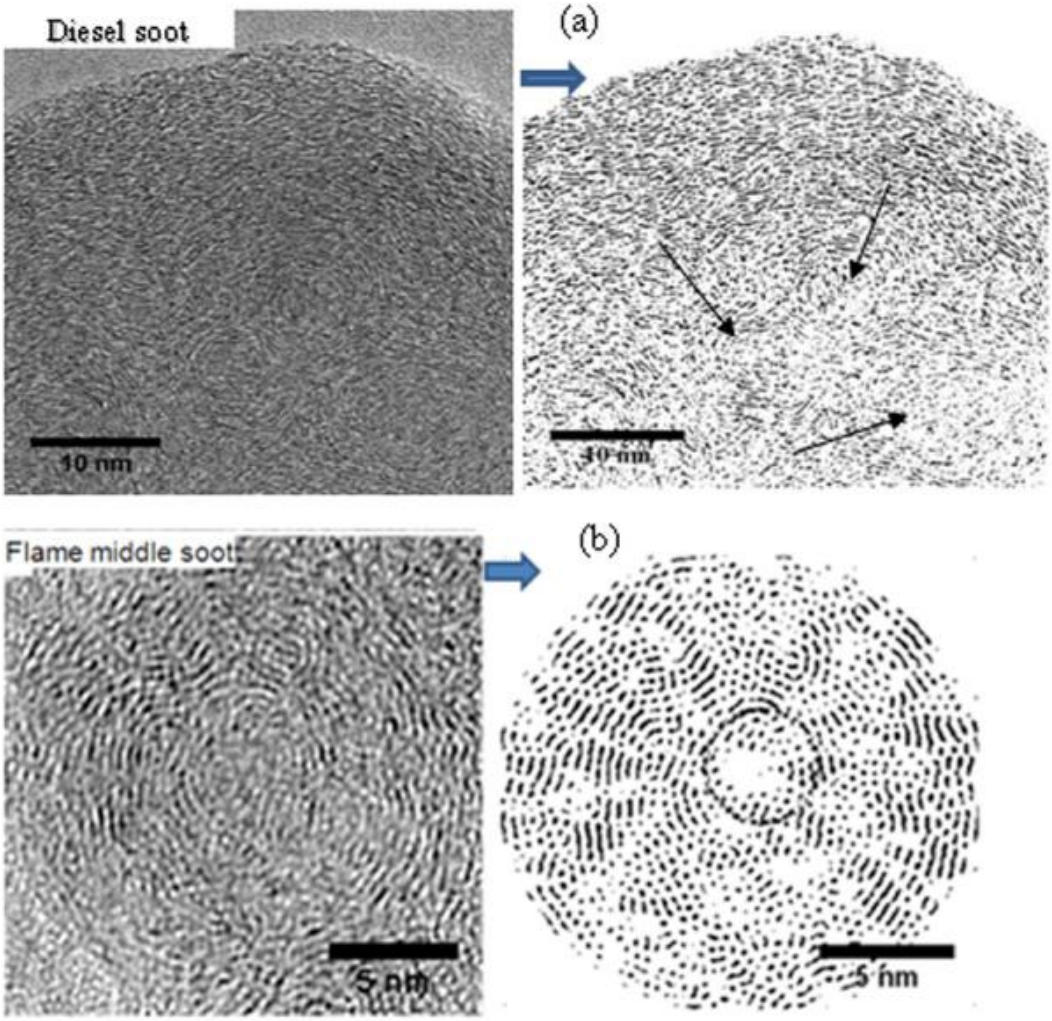


Figure 5.1**:** Structure of (*a*) diesel soot and (*b*) mid-flame soot.
Arrows indicate spherical structure.

Source: http://iopscience.iop.org/0022-3727/45/17/175302/article
Hiralal Bhowmick, S K Majumdar and S K Biswas, Tribology of soot suspension in hexadecane as distinguished by the physical structure and chemistry of soot particles (2012) *J. Phys. D: Appl. Phys.* 45 175302

2. Explore

2.1 The impact of soot on human health – group work using epidemiological data

T: Are exhaust fumes, black smoke, only a problem of aesthetics? What is the impact of these substances on human health?

[S] Each group reads one text (the Internet resources) and shares the conclusions drawn with others.

a) long exposure to diesel engine exhaust fumes increases the risk of developing lung cancer – http://jnci.oxfordjournals.org/content/104/11/855

b)the risk of cancer increases by 40% in people working in the air contaminated with diesel engine exhaust fumes – http://www.ifap.asn.au/documents/safetywaaugust_web2012.pdf

c)the composition of diesel engine exhaust fumes, harmfulness, laboratory tests and research on people and places where we are exposed to exhaust fumes – http://www.cancer.org/cancer/cancercauses/othercarcinogens/pollution/diesel-exhaust

d)Health Assessment Document for Diesel Engine Exhaust – http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=29060#Download

T: Can you tell me why the soot present in exhaust fumes is so harmful?
S:...

2.2 Properties of soot investigation

T: We may investigate what the fine coal properties are and whether they are related to the particle size.

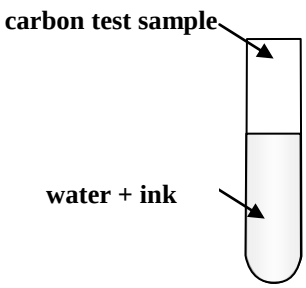
2.2 Students plan and carry out an experiment

Using reagents and equipment based on their own research question (How does the degree of fragmentation of a solid affect its properties?), hypotheses (e.g. it does not affect them. The greater the fragmentation degree, the ...) and correctly defined variables (in the case of an open inquiry).
The teacher asks the following question: Which way can be used to check experimentally how the degree of fragmentation of a solid has an impact on its properties? What kind of substance can be used? What property of a substance will you investigate? How do you obtain a substance with various degrees of fragmentation?
Students complete the worksheet.

2.2.2 Conducting the experiment (a suggestion only, students may choose other options):

Reagents: ink, charcoal or activated carbon, water.
Equipment: funnels, test tubes, beakers, filters, Pasteur pipettes, mortar and scales.
Mix the ink with the water: 250cm^{3}of water + 1 drop of ink. Pour 10 cm^{3}of water with the ink into each of the six test tubes and add 10 cm^3 of water. Next, add the same weight of

charcoal or activated carbon but of various degree of fragmentation to 5 of the 6 test tubes; the sixth one is a control tube. Mix the test tubes content thoroughly. Leave the tubes for 20-30 minutes (the time necessary for the sedimentation of particles). Compare the colours of the solutions with the control sample.
The gradual disappearance of the colour of the ink solutions with varying degree of intensity.



Alternative proposal of an experiment:

Reagents: ink or magenta dye (fuchsine), medicinal or activated charcoal, water.
Equipment: funnels, test tubes, beakers, filters, Pasteur pipettes, mortar and scales.
Mix 0.01 g of fuchsine with 250 cm^3 of water: pour 10 cm^3 of water with the ink into each of the six test tubes. To the first five tubes add an equal weight of (medicinal or activated) charcoal, but of different degree of fragmentation; the sixth tube is a control test. Mix the test tubes content thoroughly. Leave the tubes for at least 20-30 minutes (the time necessary for the sedimentation of particles). Compare the colour of the solutions.
If the dye solution is too concentrated, dilute the solution.

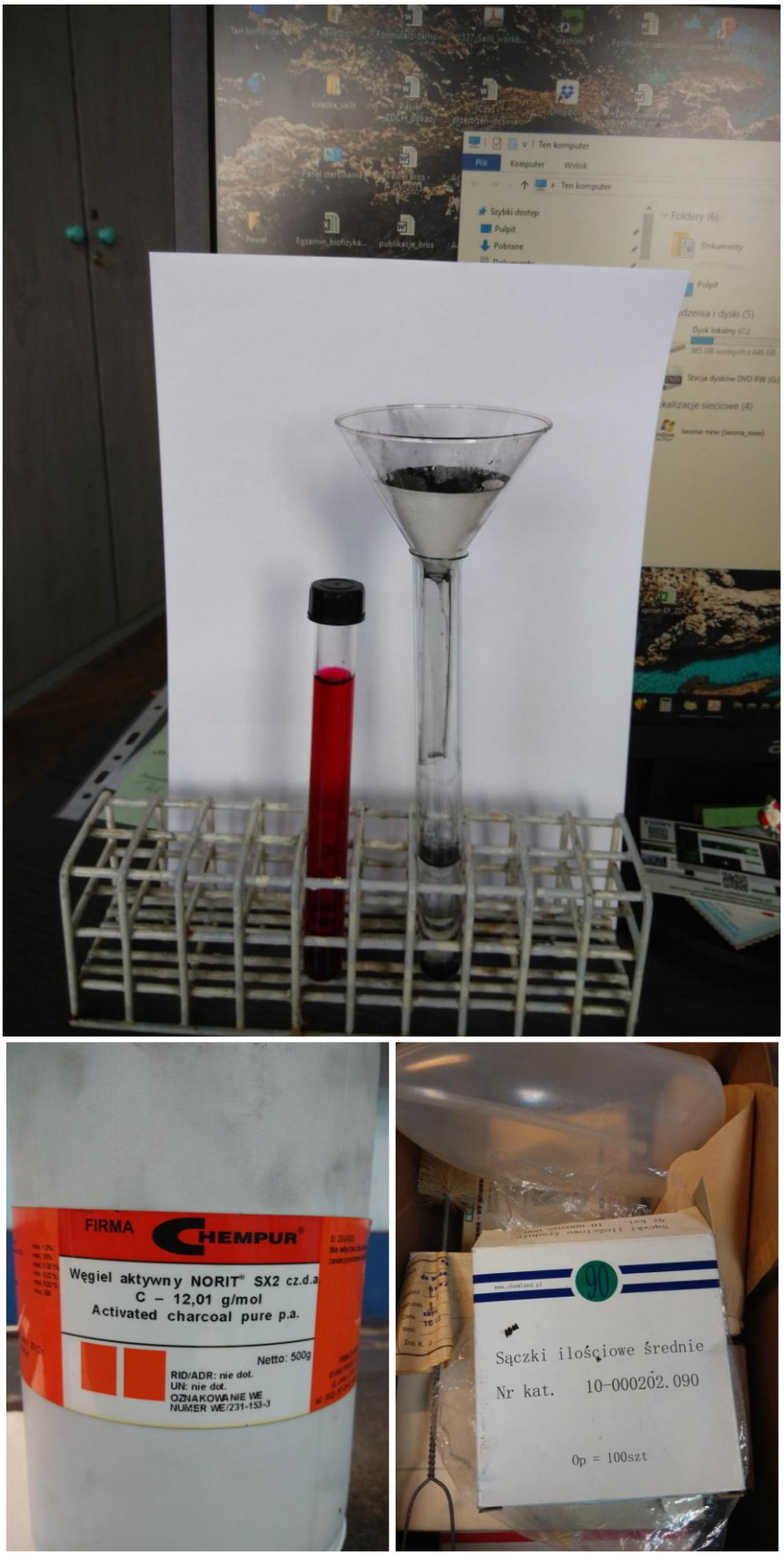


Figure 5.2: Experiment with fuchsine (Photo: Paweł Broś)

2.2.3 Analysis of the results

- What did you observe/measure? Is the colour intensity of the solution over the solid identical? Where do the change in the colour intensity of the solutions come from? What do the differences in the intensity of the colour solutions tell us?
- What is evidenced by the lack of the solution's colour in some of the tubes?

2.2.4 Presentation of conclusions

T: Have you obtained an answer for your research question?

- Compare your results with the results of other groups. Can you see any similarities or differences? What is the reason for such similarities or differences?
- What may be the reason for the observed behaviour of the ink and the differences between the coal samples applied? Try to draw a common conclusion relating to the hypothesis made.

For example: The ink is absorbed by carbon particles. The greater the degree of fragmentation, the greater the amount of the ink absorbed.

3. Explain

3.1 **Introduction of new terms:** absorption and adsorption (Fig. 5.3)

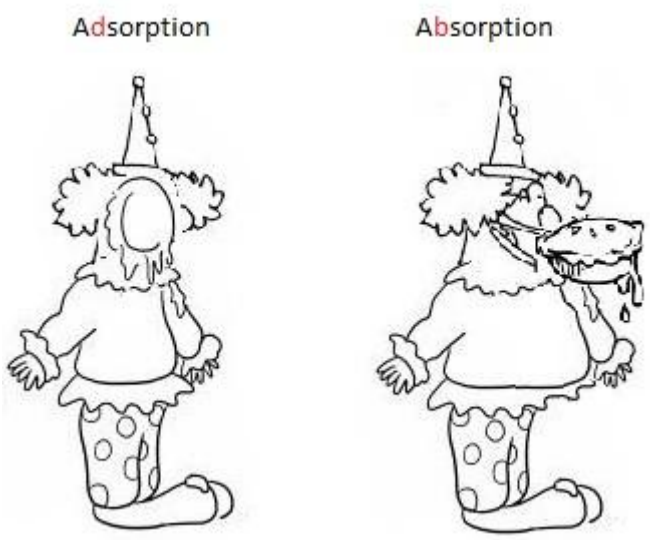


Figure 5.3: Adsorption vs. absorption (Author: Patryk Własiuk)

3.2 Why did it happen? – modelling

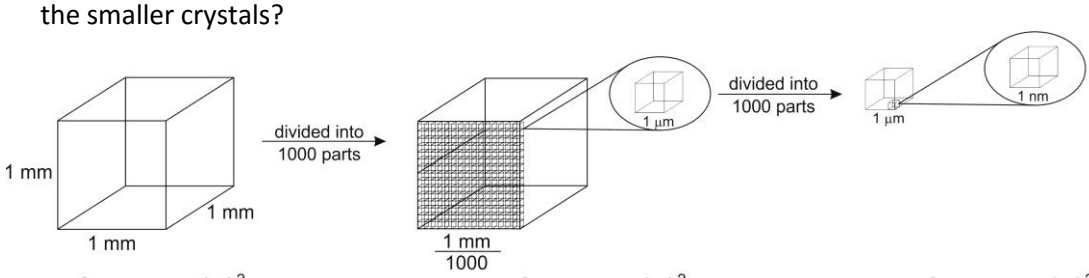
The students model the possible processes for various degrees of coal fragmentation

Suggestion A

Circles – coloured caps under which magnets are placed – represent the pigment.
Squares – magnets – represent the carbon particles (adsorbent).
Board A1 – modelling of the situation for relatively large coal particles.
Add the carbon (adsorbent) to the solution with the pigment. Have all pigment particles been absorbed – is the solution discoloured? i.e. did you manage to arrange the caps around the squares so that none of the caps were left unpaired?
Board A2
Did the reduction of the size of the adsorbent – carbon – particles change the result of the experiment?
The previously mentioned one large square can be divided into four smaller ones. And now – Have all the particles been adsorbed now? i.e. did you manage to arrange the caps around the squares so that none of the caps were left unpaired? – even if you did not manage to arrange all the caps along the sides of the four squares, certainly you must have arranged a greater number of the caps than in the previous attempt.
Why is it so?

3.3 Surface vs. volume (calculations)

T: What changes and what remains unchanged when the substance becomes fragmented?
S: The weight remains constant.
T: Let's calculate the surface area in the case of one large crystal and numerous smaller ones of the same total weight.
T: What is the surface area of one single crystal, and what is the surface area of the sum of the smaller crystals?



$S_C = 6 \cdot (a)^2$
$1\ mm = 10^{-3}\ m$
$S_c = 6 \cdot (10^{-3} m)^2$
$S_c = 6 \cdot 10^{-6}\ m^2$

$S_C = 6 \cdot (a)^2$
$1\ \mu m = 10^{-6}\ m$
$S_T = 6 \cdot (10^{-6} m)^2$
$P_c = 6 \cdot 10^{-12} m \cdot 10^{9}$
$P_c = 6 \cdot 10^{-3}\ m^2$

$S_C = 6 \cdot (a)^2$
$1\ nm = 10^{-9}\ m$
$S_T = 6 \cdot (10^{-9} m)^2$
$S_c = 6 \cdot 10^{-18} m \cdot 10^{18}$
$S_c = 6\ m^2$

T: What conclusions can be drawn from those calculations?
S: The smaller the crystals, the larger the total surface area. It is a geometric dependency
The students may draw conclusions on the relationship between the size of the surface area and fragmentation: the greater the degree of fragmentation of a solid (smaller particle diameters), the greater the surface area.

Suggestion B

Circles – coloured caps under which magnets are placed – represent the pigment.
Squares – magnets – represent the adsorben t(Fig. 5.4).

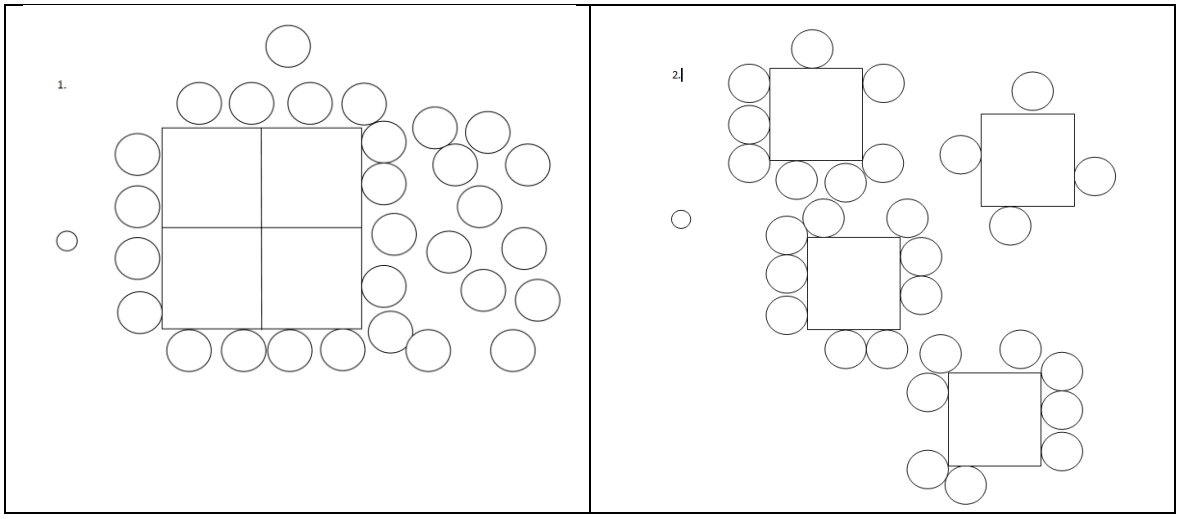


Figure 5.4: Board B1

Add the adsorbent to the solution with the pigment. Have all pigment particles been absorbed – is the solution discoloured? i.e. did you manage to arrange the caps around the squares so that none of the caps were left unpaired? (Fig. 5.5)

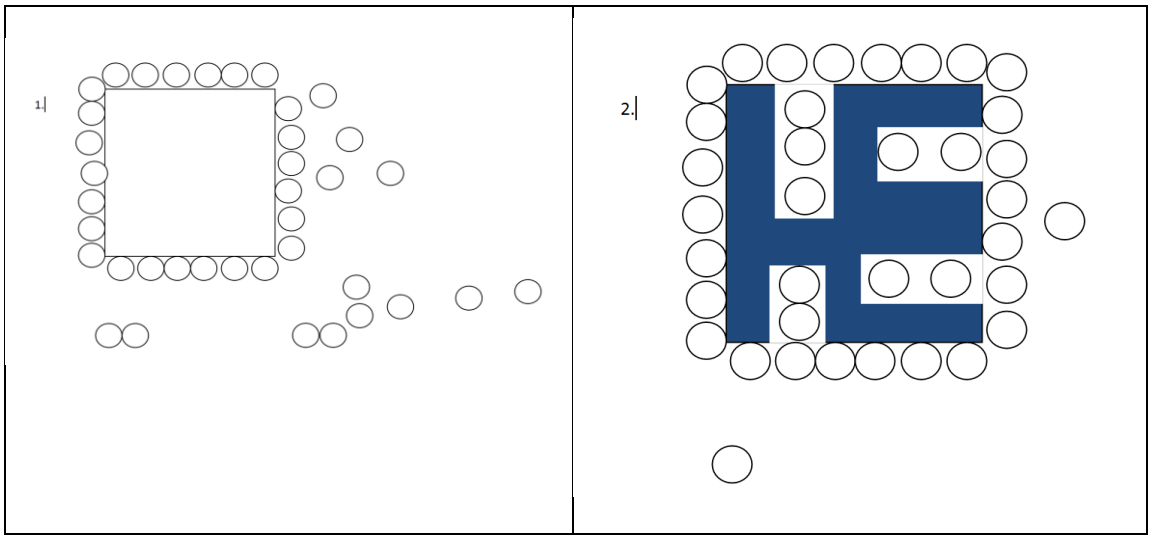


Figure 5.5: Board B2

It is possible to remove from an adsorbent (the square) particle some fragments to obtain corrugated edges? Has the change of the surface character influenced the experiment outcome?

Possible interactive exhibit (Fig. 5.6):

Figure 5.6: Interactive presentation of a mixture & adsorption (Photo: Dorota Kamińska)

4. Extend

4.1 Surface vs. sorption capacity

T: Have you noticed in your experiment any dependency between the degree of fragmentation, total surface area and sorption capacity?

S: The higher degree of fragmentation the greater the substance's sorption capacity.

T: Which tenement houses in Krakow get dirty faster – those whose facades are covered with smooth plaster, or the more fashionable ones, covered with porous plaster?
– a presentation of two photos
T: What do you think, why is it so?

Teaching comment:
The previous experiment may be repeated using the substances of more or less porous surface but of the same particle size.
Teachers can read more about the non-staining surfaces in Lesson 10

S: Dirt enters the pores of the plaster.

4.2Introduction of the concept of a specific surface area

T: Going back to the topic of the harmful effects of soot. Can you now answer the question: why is soot, which is in the form of small particles having a large and 'developed' i.e. porous surface (30 - 50 m^2/g) so harmful?
S: The harmfulness of soot may be due to the fact that substances dangerous to human health are adsorbed on its surface.
T: They may be, for example, carcinogenic aromatic hydrocarbons (BaP). Small soot particles are the perfect 'means of transport' for the adsorbed substances, which otherwise would not have reached that far in the respiratory system (to the lungs).

4.3. Presentation and discussion of a soot particle model (Fig. 5.7)

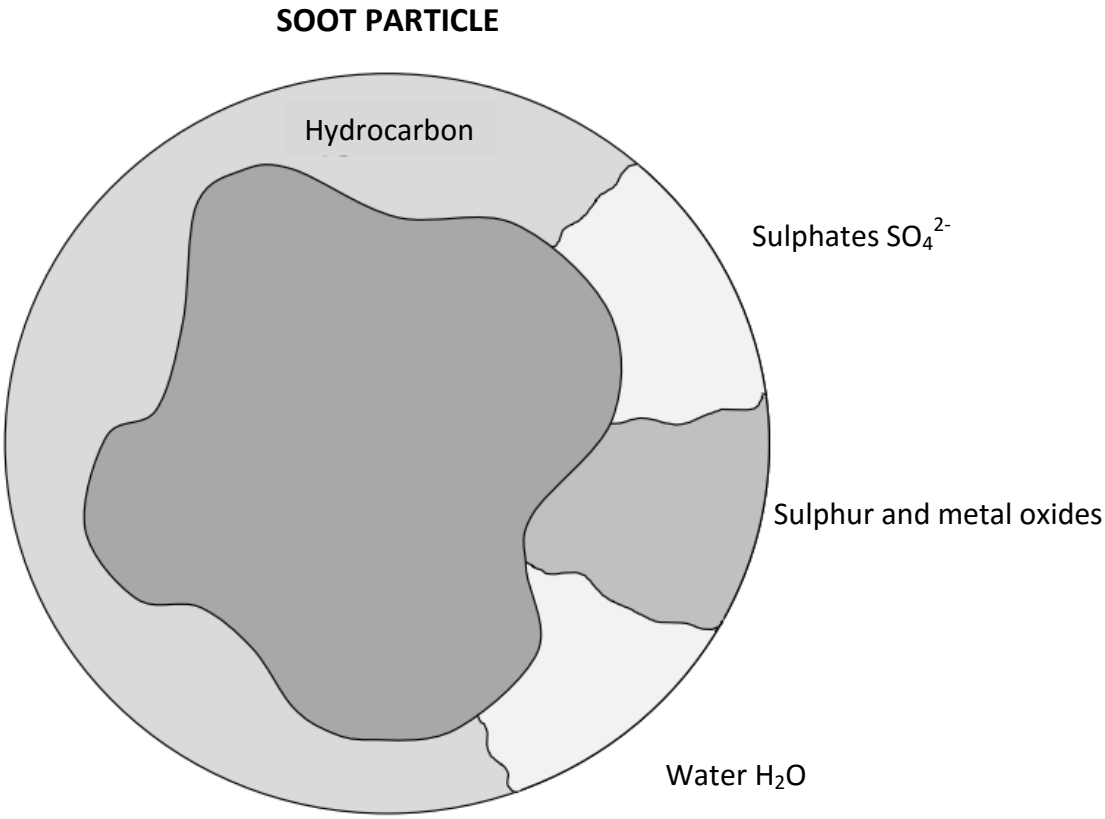


Figure 5.7: A soot particle model
(http://s1.blomedia.pl/autokult.pl/images/2011/03/czastkasadzy.jpg)

4.4. Final discussion – what to do about smoky cars?

T: The invention of cars was associated with the emergence of a number of new threats. What threats can you identify?

S: Car accidents, air pollution from exhaust fumes and petroleum products, consumption of non-renewable raw materials (iron ore, oil), emergence of hardly degradable waste (scrap yards), exhaust fumes poisoning of people.

T: And can you imagine now living on the Earth without car transport?
What can be done and what is being done to reduce the negative impact of transportation? – discuss the issues in small groups and present your conclusions.

S: E.g. a reduction of road transport to the benefit of rail transport, banning cars from city centres, the introduction of legislation concerning the level of emissions, electric and hybrid motors, buying agricultural products that are grown no farther than 50 km from the place of residence ...

T: What should be done to implement your ideas in real life?

S: introduce prohibitions, orders and convince people to behave in the proper way.

T: What you talk about is the need for proper management (including the introduction of regulations) and education, including the environmental one. Presentation of the photo (Fig. 5.8).

Figure 5.8: Euro6 bus (Source: www.scania.pl)

11. European regulation (governance)

T: Do you know what Euro6 means?
Find an answer in available resources e.g. …

http://noxy.eu/pl/normy-technologia-scr
http://www.autoexpress.co.uk/car-news/consumer-news/90816/euro-6-emissions-standards-what-do-they-mean-for-you

5. Evaluate

5.1 Gap fill

.....(Soot) is a mass of impure carbon particles resulting from the incomplete .....(burning) of hydrocarbons.

5.2 Soot is harmful to health because:

A) It is black
B) Particles are so small
C) Carbon particles adsorb other harmful compounds
D) It is a component of exhaust gases

5.3 Match a picture (left or right) and a concept: adsorption or absorption (for simplification, a phase boundary is determined by a straight line (Fig. 5.9)

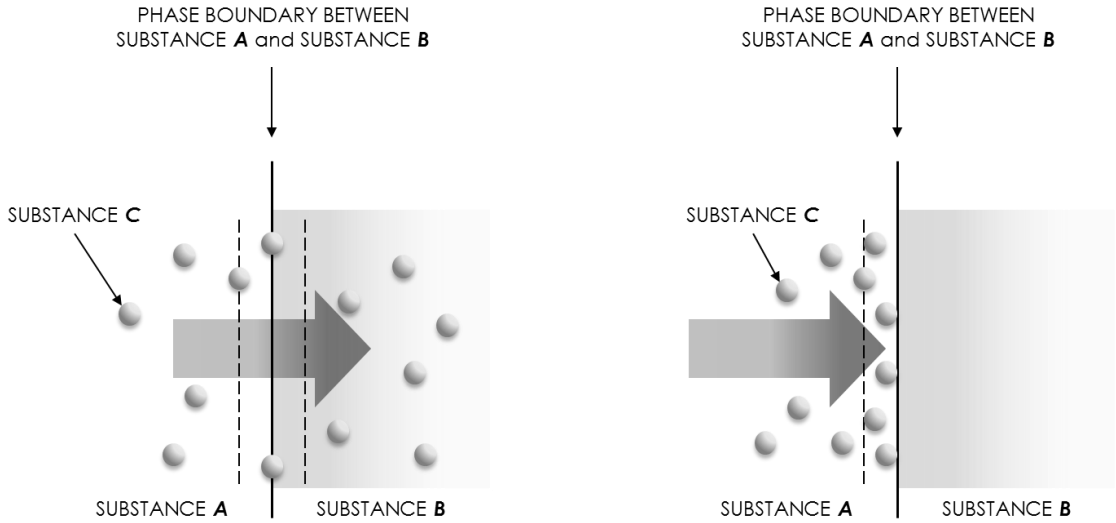


Figure 5.9: Adsorption vs. absorption

5.4 Select proper words which indicate a dependence

The smaller/higher degree of fragmentation, the smaller/bigger the crystals,
The smaller/larger the total surface area, the smaller/larger the sorption capacity.

table 5.1.

Example of a student's knowledge self-assessment after the lesson no. 5: *Cars, Soot & Sorption*

Topic: *Cars, Soot & Sorption*	With substantial help from the teacher	With help from the teacher	Independently without outside help
1. I can define absorption, adsorption, specific surface area			
2a. I can explain what the phenomena of absorption and adsorption consist of 2b. I can explain how the degree of fragmentation of a solid affects its properties			
3. I can give the basic composition of car fuels			
3. I can describe the negative impact of soot on human health			
4. I can propose the methods for reducing air pollution			
5. I can plan and carry out a demonstration experiment presenting the adsorption phenomenon			

Homework

In groups of students – build the model of Carbon structures existing in soot and determine the size; draw conclusions

Use animation and drawings (see students' materials):

- animation – nanotubes: http://www.fizyka.iss.com.pl/nanorurki/
- drawings – nanotubes: http://www.fizyka.iss.com.pl/nanorurki/

https://www.youtube.com/watch?v=kWTrZxt4j50
http://www.shutterstock.com/video/clip-1507634-stock-footage-conceptual-animation-showing-the-structure-of-carbon-nanotubes-seamless-looping-alpha-channel.html

Materials: paper, scissors, pencil, ruler or optionally plastic tubules for drinks, scissors, ruler, Glutex glue or Super Glue

Time needed (in the case of one person and C186 nanotube) – 10 hours

Various kinds of modelling can be proposed as interactive exhibits.

At the end of the lesson a teacher might ask students:
What have you learned by conducting experiments at today's meeting?
Where in everyday life can you use the sorption properties of substances?

Ask the students to show what they have learned during this lesson, creating a mind map (http://cmap.ihmc.us/products/) or a concept map in Mindomo.

6

Size Makes a Difference

Lesson No.6

Size Makes a Difference

Learning objectives:

- **Introduction of the concepts: top-down, bottom-up methods;**
- **Becoming familiar with various methods of obtaining nanomaterials.**

Learning outcomes:

A student is able to:

- **specify two strategies for preparing nanoparticles.**

Time: 45-60 minutes

1. Engage (Introduction)

T: Have you ever seen a catalyst?
S: ...

1.1 Presentation of a catalyst developed at Jagiellonian University in Krakow

T: Can the structure of the catalyst be seen with the naked eye?
S: No.
T: What can we use to observe it?
S: A magnifier, currency detecting microscope, USB microscope, optical microscope, maybe.
T: Try...

1.2 Experiment

Students watch samples of catalysts using optical tools. They are not able to distinguish various substances.
T: Electron microscopy has recently become an almost indispensable tool in the study of catalysts.

1.3 Presentation of a photo No.6.1

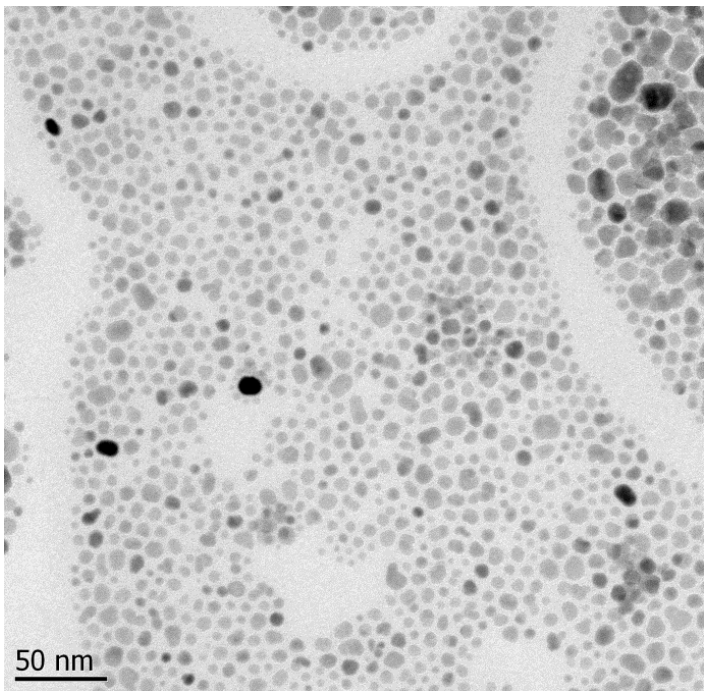


Figure 6.1: Picture of Fe_3O_4/Fe_2O_3 taken using electron microscopy (Photo: Andrzej Kotarba)

2. Explore

2.1 Analysis of the electron microscope photos of the catalysts

T: What can you see in these photos?

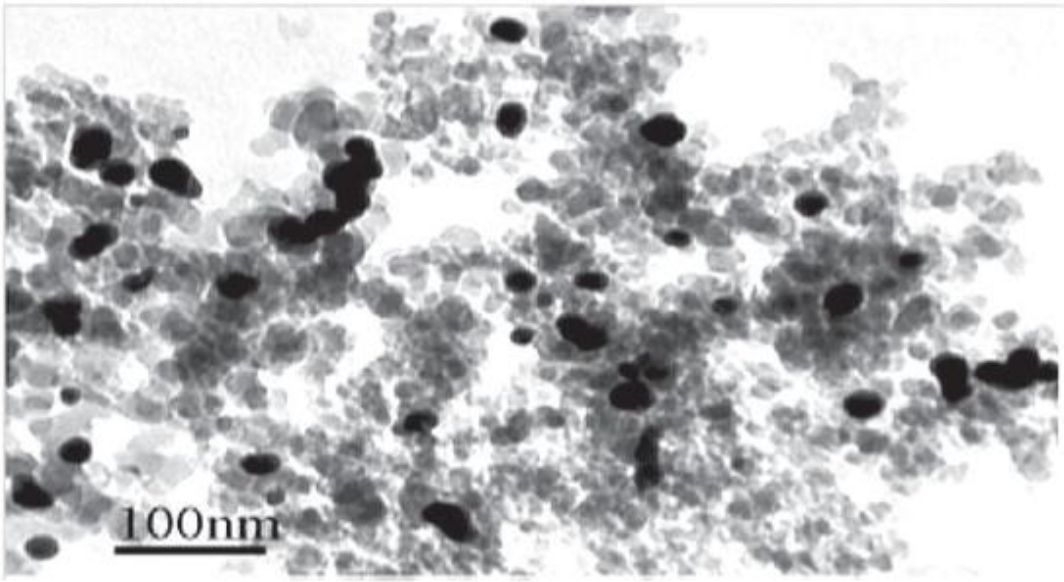


Figure 6.2: Photo of the Au/SiO_2 catalyst made using the TEM technique (X. Jiang, H. Deng, X. Wang, Colloids and Surfaces A:Physicochem.Eng.Aspects, 358 (2010) pp.122–127)

T: Electron microscopy allows for accurate analysis of a sample structure and, above all, it provides information about the shape and particle size distribution (the relationship between the number of the catalyst's grains and their size, generally – matching *value with its* collection *frequency*). By measuring the number of particles, one may determine the distribution of their size and thus also establish the relationship of the catalyst's activity and the size of the grains.

2.2 Calculation – activity for students

T: Having the selected images with the scale marked and a simple tool in the form of a ruler, try to determine the relationship between the number of the catalyst's grains and their size. The size is understood to be the largest possible to measure the length of the section. Plan a method of noting down and presenting the results.

Teaching note:
The results may be collected in a table of a selected spreadsheet programme e.g. Excel – presentation in the form of a bar chart (histogram). It is worth discussing the pros and cons of various presentation methods. The following (Fig. 6.3) presents a sample work of the catalyst in Figure 6.2:

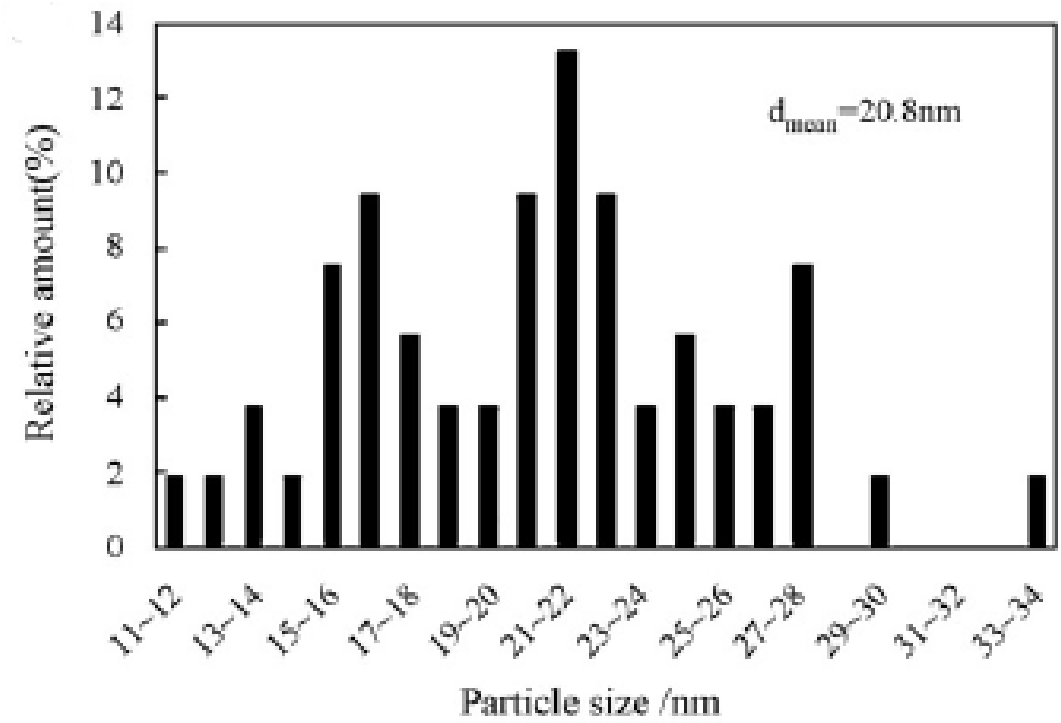


Figure 6.3: Particle size distribution (X. Jiang, H. Deng, X. Wang, Colloids and Surfaces A:Physicochem.Eng.Aspects, 358 (2010) pp.122–127)

T: What do your charts show? What conclusions can you draw from that analysis? What is the average grain size of a given substance (catalytic material)?

2.3 Look in the literature/online for the size of the grains/crystals of other chemical substances that are not used as catalysts and compare the data with your results. What are the outcomes of such a comparison?

Students present their results.

T: Grains/crystals of acting metal oxide catalysts are approx. the size of a few nanometres and e.g. the size of the unit cell of the crystal of sodium chloride is $4.225 \cdot 10^{-10}$ m, so 0.4225 nm); potato starch granules size is 15-100 µ, DNA's diameter – 2.5 nm.

2.4 Brainstorming: How to create such a catalyst the fineness/particle size of which would be a few nanometres?

Teaching note
Brainstorming – Osborn technique. He claimed that two principles contribute to 'ideative efficacy', these being: defer judgment and reach for quantity.
Following these two principles were his four general rules of brainstorming (see below), established with the intention to reduce social inhibitions among group members, stimulate idea generation, increase overall creativity of the group.

(Source: https://en.wikipedia.org/wiki/Brainstorming)

- *Focus on quantity*
- *Withhold criticism*
- *Welcome unusual ideas*
- *Combine and improve ideas*

Discussion can be also based on the materials published on the Internet e.g. FROM NANO TECHNOLOGY TO NANO CATALYSTS: A QUANTUM JUMPA JUMPS. Tajammul Hussain**,** http://www.ncp.edu.pk/docs/iss/talks/plannary_sessions/p_d4_dr_tajammul.pdf

How to get a substance having a particle size on the nanometre level? Is it possible?

3. Explain

3.1 Teacher's presentation: Strategies for creating catalytic materials

The scheme of obtaining nanoparticles using the 'top-down' and 'bottom-up' methods is presented in Figure 6.4. (Source: CHEMIK (2014), **68**, 9, pp. 766–775)

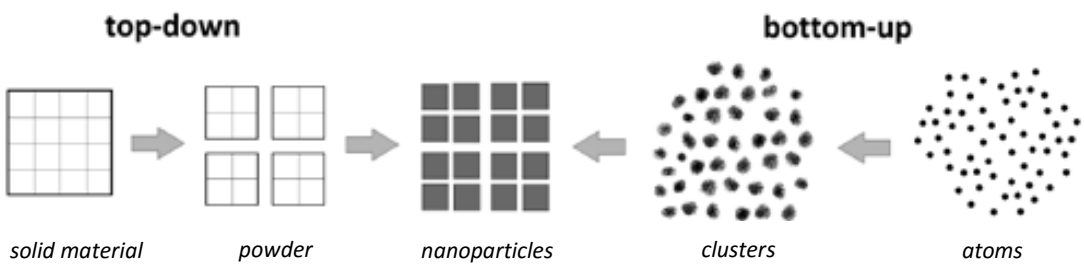


Figure 6.4: Nanoparticle synthesis scheme using the 'top-down' and 'bottom-up' methods

Two examples of analogies will be illustrated below to show how daily life experiences can help in understanding methods of obtaining nanoparticles.

Teaching comments:
This analogy prepared by the teacher (passive analogy) is used to better understand the newly-understood phenomenon that by comparing something to something familiar becomes understandable (the so-called "making the strange familiar")

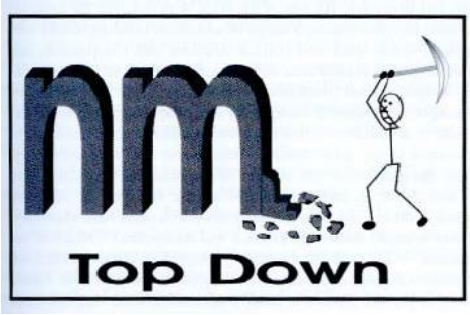


Figure6.5: Grinding, the application of high energy 'grinders'
(http://www.ncp.edu.pk/docs/iss/talks/plannary_sessions/p_d4_dr_tajammul.pdf)

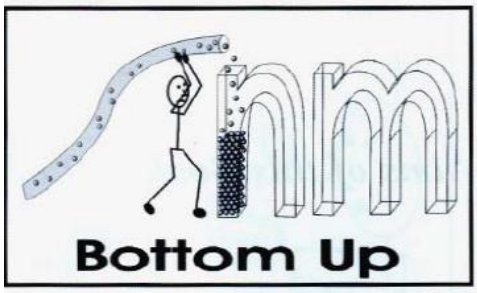


Figure6.6: Putting atoms together i.e. synthesis
(http://www.ncp.edu.pk/docs/iss/talks/plannary_sessions/p_d4_dr_tajammul.pdf)

5.Evaluate

5.1 Name all elements in the picture presented below (Fig. 6.7):

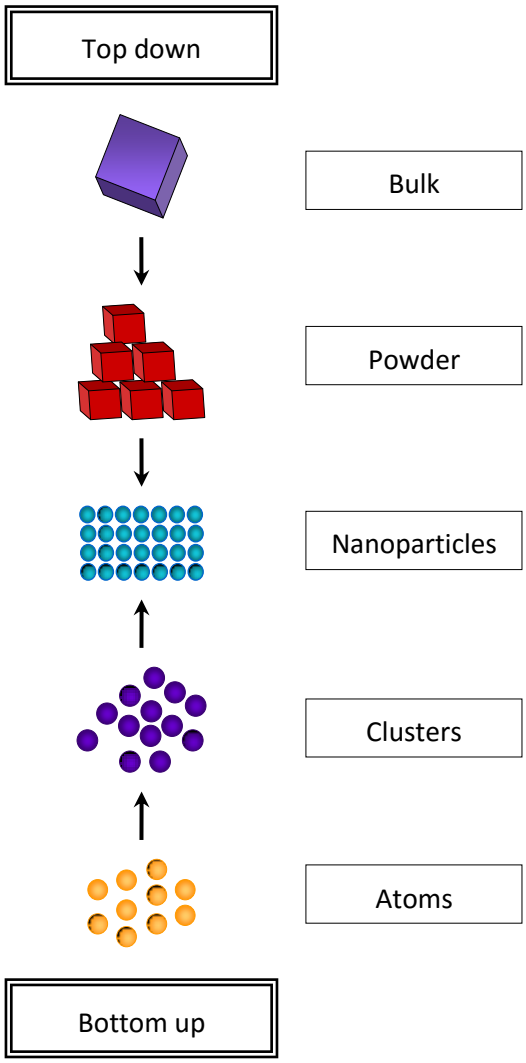


Figure 6.7: Approach to nanoparticles construction
(G. Madhumitha and Selvaraj Mohana Roopan, Devastated Crops: Multifunctional Efficacy for the Production of Nanoparticles, http://www.hindawi.com/journals/jnm/2013/951858/)

5.2 Example of a student's knowledge self-assessment after the lesson No. 6: *Size makes a difference*

table 6.1

Example of a student's knowledge self-assessment after the lesson No. 6: *Size makes a difference*

Topic: *Size makes a difference*	With substantial help from the teacher	With help from the teacher	Independently
1. I can define the concepts: top-down, bottom-up methods			
2. I can specify various methods for obtaining nanomaterials			
3. I can introduce two strategies for preparing nanoparticles			
4. I know the rule defining the dependence of the number of grains (monocrystalline) on their size			

At the end of the lesson a teacher might ask students:

What have you learned by conducting all the exercises in today's meeting?

Where in everyday life can encounter the topic of today's meeting?

7

A Catalyst

Lesson No.7

A Catalyst

Learning objectives:

- **Introduction of the concepts: active catalytic centre;**
- **Becoming familiar with the typical features of a good catalyst;**
- **Demonstrating the dependence between the size of a specific surface area, the number of walls and corners and the activity of the catalyst, and between the application of the roasting process and the size of a specific surface area.**

Learning outcomes:

A student is able to:

- **characterise a catalyst in terms of its most useful features: activity, stability, selectivity, preparation process, the possibility of recycling and active surface,**
- **determine the relationship between the number of embryos of crystallisation and the crystal size,**
- **plan and carry out demonstration experiments examining the catalytic activity of nanomaterials,**
- **define and explain the term 'siltering'.**

Time: 90 minutes

1. Engage (Introduction)

1.1 A discussion: What does a ‘good’ catalyst mean?

T: What do you think, *what qualities should a good catalyst have?*
S: It should be ‘efficient/effective’.
T: What guarantees the high efficiency/effectiveness of a catalyst?
S: ...
T: That will be the topic of today's classes.

What does a ‘good’ catalyst mean? This can be a question for an example of an interactive exhibit.

1.2 Demonstration of the nanoparticles precipitation, e.g. of gold (a video or demonstration of an experiment).
https://www.youtube.com/watch?v=SBkGZiTxHKE
https://www.youtube.com/watch?v=urmi99jQSZY

T: What can be changed in order to get the best (required) crystals size? What is the relationship between the reaction conditions and the product form?
S: Change the reaction temperature, rate of mixing the reactants, reactant concentration, add other substances e.g. which have an ion in common
T: Which of those would you like to examine?

2. Explore

An example:

2.1 **Experiment 7.1** – Examination of the impact of the addition of electrolytes and non-electrolytes (egg white) on colloidal gold solution (http://www.nanoeis.eu)

2.2 **Experiment 7.2** – Examination of the influence of temperature on the form of the product of lead(II) nitrate(V) with potassium iodide reaction

2.2.1 Planning an experiment

Green colour – possible students' ideas

Research problem: *How will the temperature influence the form of the lead(II) iodide residue?*
Hypothesis: e.g. The size of PbI_2 crystals (does not) depend(s) on the precipitation temperature. The higher/lower the solution temperature, the larger/smaller the forming crystals
Planning the study: Perform the precipitation in several, e.g. three/four, different temperatures e.g.: 20°C, 50°C, and the boiling point.
Determining variables: independent variable -$Pb(NO_3)_2$ solution temperature dependent variable - crystals size control variables -$Pb(NO_3)_2$ and KI solutions concentration, volume of the solutions used
Measurements: Observation of the crystal size can be conducted by naked eye as well as with the use of an optical microscope. Single crystals photos allow zoom in and comparison.

Precautions:

Under no circumstances should lead salt contact the skin; therefore, it is necessary to work wearing protective gloves. Please refer to the Safety Data Sheets of the substances used:

$Pb(NO_3)_2$ -

KI – the substance is not classified as hazardous.

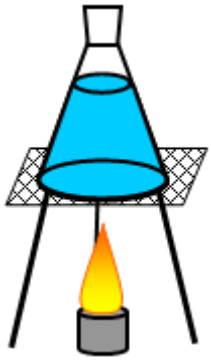
Disposal of residues: put the content in the container marked with Cr.

Experimental part (*suggestion only, students may suggest something else*):

- Room temperature precipitation
  - Reagents: 0.25 M $Pb(NO_3)_2$ solution, 0.5 M KI solution,
  - Equipment: 2 beakers,

- Procedure: Add 10 cm^3 of the KI solution to the beaker filled with 10 cm^3 of the $Pb(NO_3)_2$ solution;

- Hot precipitation
  - Reagents: 0.25 M $Pb(NO_3)_2$ solution, 0.5 M KI solution,
  - Equipment: 500 cm^3 crystallizer, 250 cm^3 Erlenmeyer flask, glass rod, tripod, heating net, burner.
  - Procedure: Heat the flask filled with 100 cm^3 of $Pb(NO_3)_2$ solution, bring it to the boil, and then add small portions of 10 cm^3 to the KI solution (room temperature) until the solution becomes slightly yellow in colour. Leave the flask to cool down, and then put it in a crystalliser with water (temperature about 20^0C, room temperature). The steps must be repeated for the two other temperatures of $Pb(NO_3)_2$ solution.



2.2.2 Conducting the experiment

Students should check their proposed answers to the research question (assumptions) by comparison with the results of the experiment.

2.2.3 Results analysis, presentation and reflection

What is the form of the residues obtained?
What similarities and differences are there between the results and conclusions obtained by the various groups? How did they arise?
Is the hypothesis confirmed or disproved?
Have you obtained an answer for your research question?

3. Explain

T: The more crystal nuclei are formed in the shortest possible time, the greater the number of smaller crystallites. If, as a result of the applied synthesis procedure, the number of crystal nuclei formed is small, they will grow and eventually there will be fewer of them, and thus the crystals will be larger.

4. Extend

T: Based on the knowledge from previous lessons, what can you say about the specific surface area of the residue? Is it the same?

4.1 Search on the internet – What more can be done with the obtained residues of substances to make them have different surface areas? *One of possible answers is* – sintering

T: We have already investigated the impact of the substance surface area on the efficiency of the adsorption process. Let's now consider how to verify experimentally whether the specific surface area of a substance can affect the reactivity of the resulting material?

T: We may also go back to the first classes and check the catalytic activity in hydrogen peroxide decomposition reaction.

Explore II

4.2 **Experiment 7.3**

Preparation of iron(III) oxide crystallites of various specific surface areas. Testing their catalytic reactivity e.g. in the decomposition reaction of hydrogen peroxide (guided inquiry).

Teaching note:
Depending on the time allocated for the classes, now we may proceed to obtaining/preparing the iron(III) oxide in the reaction of thermal decomposition of iron(III) hydroxide, or use the ready-to-use iron(III) oxide and, through sintering, obtain crystallites of various specific surface areas. Sintering, depending on the capabilities of the equipment, can be performed: in a muffle furnace, microwave oven using the GST technique (German: Graphit-Suszeptor-Tiegel-Technik) (Arnim Lühken, 2001), or in a crucible over a gas burner.

4.2.1 Planning

Green colour – possible students' ideas

Research problem: What is the relationship between the size of iron(III) oxygen crystallites and their catalytic activity?
Hypotheses: Unroasted crystallite exhibits greater/smaller activity, no differences are observed.
Planning the study: The reaction rate may be measured through the observation of the quantity of foam formed at a given period.
Determining the variables: independent variable Size of iron(III) oxide crystallite. dependent variable Time in which the column of foam of a specific height will be obtained – e.g. reaching the edge of the container in which the experiment is carried out. control variables concentration of hydrogen peroxide, composition of the H_2O_2 + dishwashing liquid solution, reaction temperature, volume of the test solution, weight of the oxide added, size of the tube/container in which the experiment is carried out.
Measurements

Reagents and materials: solid iron(III) oxide, hydrogen peroxide solution, dishwashing liquid solution.
Equipment: microwave, two melting-pots, two cylinders, gas burner and trivet.

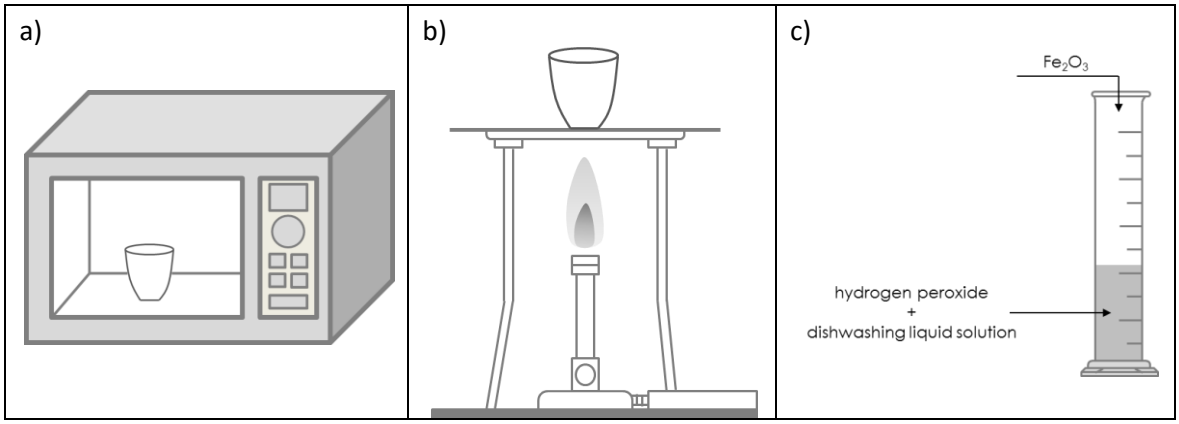
Precautions:

H_2O_2 -
Fe_2O_3 – the substance is not classified as hazardous.
Disposal of residues: Dilute the unreacted hydrogen peroxide with plenty of water and then pour into the container marked with N as 'non-flammable liquids'.

4.2.2 Conducting an experiment

Method 1.
Divide the resulting sample of Fe_2O_3 crystallite into two parts. Leave the first one unroasted, and roast the other part in a microwave oven in a crucible placed in the GST element for about 10 minutes (Fig. 7.2a). Allow the sample obtained to cool down and then pour it out into the container prepared by you.

Method 2.
Divide the resulting sample of Fe_2O_3 crystallite into two parts. Leave the first one unroasted, and roast the other part in a melting-pot placed on a mat and a tripod over a burner for about 1 hour (Fig. 7.2b). Allow the sample obtained to cool down and then pour it out into the prepared container.
Then proceed to examine the reactivity of the obtained crystallites in the decomposition reaction of hydrogen peroxide solution (Fig. 7.2c).



Students should check their proposed answers to the research question (assumptions) with the results of the experiment.

4.2.3 Analysis of the results, drawing conclusions

Students present and discuss the results and conclusions with other groups, answering the following questions:

- What similarities and differences are there between the results obtained by the various groups?
- What is a source of these differences?
- What similarities and differences are there between conclusions obtained by various groups?
- How did they arise?
- Is the hypothesis finally confirmed or disproved?
- Have you obtain an answer for your research question?

T: What would you correct in that experiment procedure to make the results more reliable? e.g. roasting time, temperature at which roasting is performed. Using a muffle oven each time, the time and temperature of roasting are strictly defined and the repeatability of the resulting crystallite, e.g. the size of the grains, is preserved. Selection of the appropriate hydrogen peroxide concentration.

Explain II

Teaching note:
It is important that the students were aware, after performing the experiment, that roasting of a substance may affect the specific surface area of the substance obtained, e.g. catalyst, as that is the parameter we want to examine in the context of the catalyst reactivity.

4.3 Presentation of a pictures prepared using scanning acoustic microscopy

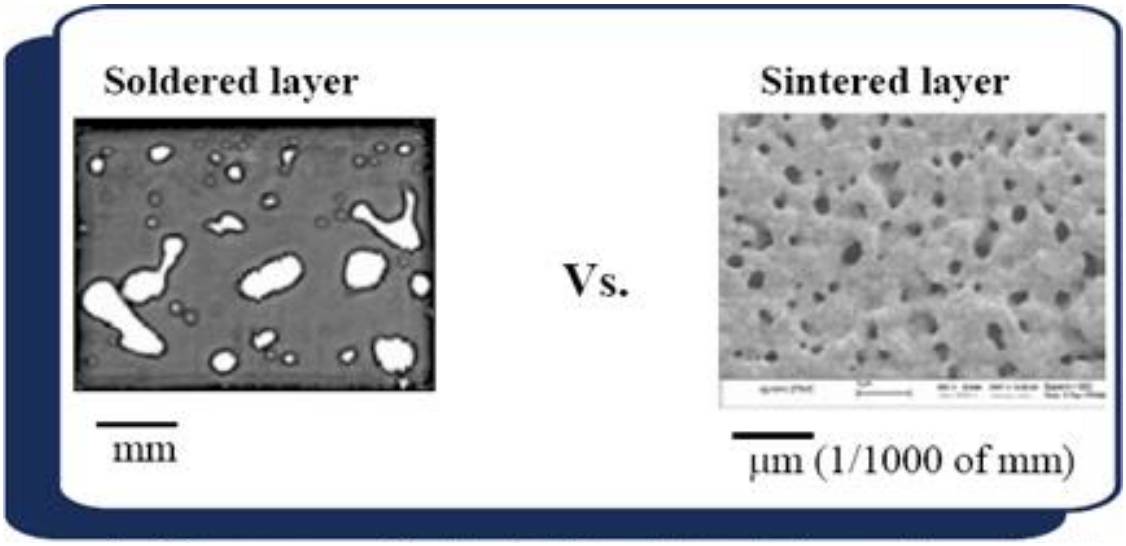


Figure 7.1: Microstructures of soldered (left) and sintered die-attach layer (right). Scanning acoustic microscopy reveals millimeter-size voids in the soldered layer underneath the die, while scanning electron microscopy of the sintered silver layer shows uniformly distributed micron-size pores.

Source: A publication of the National Electronics Manufacturing Center of Excellence (retrieved from: http://www.empf.org/empfasis/2006/nov06/lowtemp.html)

and a model (Fig. 7.4)

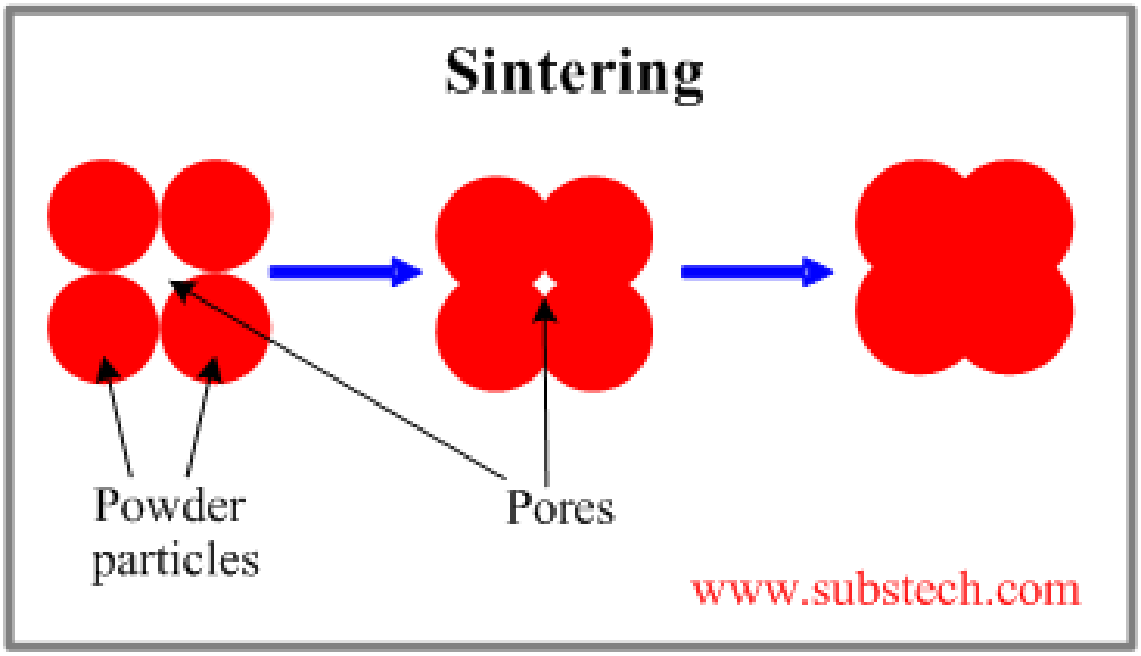


Figure 7.2: Model of sintering (Dmitri Kopeliovich, Sintering of ceramics, retrieved from: http://www.substech.com/dokuwiki/doku.php?id=sintering_of_ceramics)

T: Roasting/sintering in a microwave oven takes place at a temperature above the temperature of the burner. The higher the calcining temperature, the move the effect of 'lumps' becomes visible to the naked eye.
The calcination temperature of iron oxide (III) affects the crystallite size, and thus its surface area. The larger the surface area of the catalyst, the greater the catalytic activity.

Extend II

Introduction of a concept of 'an active centre/site'

T: The catalyst activity depends largely on the number of locations on the surface that are actively 'involved' in the catalysis reaction i.e. the number of active centres/sites. These are mainly atoms located at the corners and edges of the grains/crystals. The greater the number of the crystal walls, corners and edges, the greater the catalyst activity.
As we demonstrated in the calculations during the previous classes – the greater the fragmentation, the greater the catalyst surface area, the greater the number of active sites, and it is the number of active sites that determines the so-called catalytic activity.
Increasing the active surface area of catalysts has an impact on both their adsorption properties and reactivity.

Features of a good catalyst – a snowball discussion

T: What should be the qualities of a good catalytic material (define based on the above exercises and references)?

Teaching note:
Description of snowballing technique

1. *A relevant question is asked or scenario described.*
2. *Pupils individually write down their thoughts, opinions and/or suggestions.*
3. *Pupils form pairs and compare answers. They discuss their positions and reach an agreed or compromised position on the issue, which is then recorded.*
4. *Pupils move into groups of four and undertake a similar process. Another agreed position is reached and noted.*
5. *The group of four becomes a group of eight and the process is repeated. A further agreed position is reached*
6. *As the groups get bigger it will be necessary to elect a spokesperson/facilitator, time-keeper, resource manager, scribe etc.*
7. *The final whole-class position is then discussed and justified.*
8. *The view of any pupil who objects strongly to the agreed position could be recorded if the individual feels that their opinion is not adequately represented.*
9. *A debrief afterwards might explore not only the knowledge and understanding, but also the process of the activity: how did pupils come to a decision? How was a compromise reached?*

Source: Active Learning and Teaching Methods for Key Stage 3 (http://www.nicurriculum.org.uk/docs/key_stage_3/ALTM-KS3.pdf)

S: High catalytic activity, high specific surface area, a large number of walls and a large number of corners. Furthermore, it should be cheap, easily accessible, environmentally friendly, easy to obtain, with high mechanical and thermal resistance and resistance to poisons i.e. substances that reduce its catalytic activity.

Teaching note:
Observation sheets and rubrics can be used to evaluate students' communication skills as well as knowledge and reasoning presented during the discussion.

5. Evaluate

Group work

The class is divided into groups, and the representative of each group rolls the dice No. 1 in order to get a phrase to elaborate on.

The phrases to elaborate on are located on the dice's sides, and are:

- *nanomaterial,*
- *catalyst,*
- *catalyst's characteristics,*
- *specific surface area,*
- *catalytic activity,*
- *active components*.

Students prepare a note on the selected topic. The note must fit on a sheet of paper with the dimensions corresponding to those of the dice's side. Each group sticks their note on one side of dice No. 2.

Preferably, the number of dice No. 2 should be equal to the number of student groups (the same refers to the number of sheets of paper, so that each group could prepare an adequate number of the note's copies) – in such a case, each group will have an opportunity to evaluate all the notes provided by the other groups.

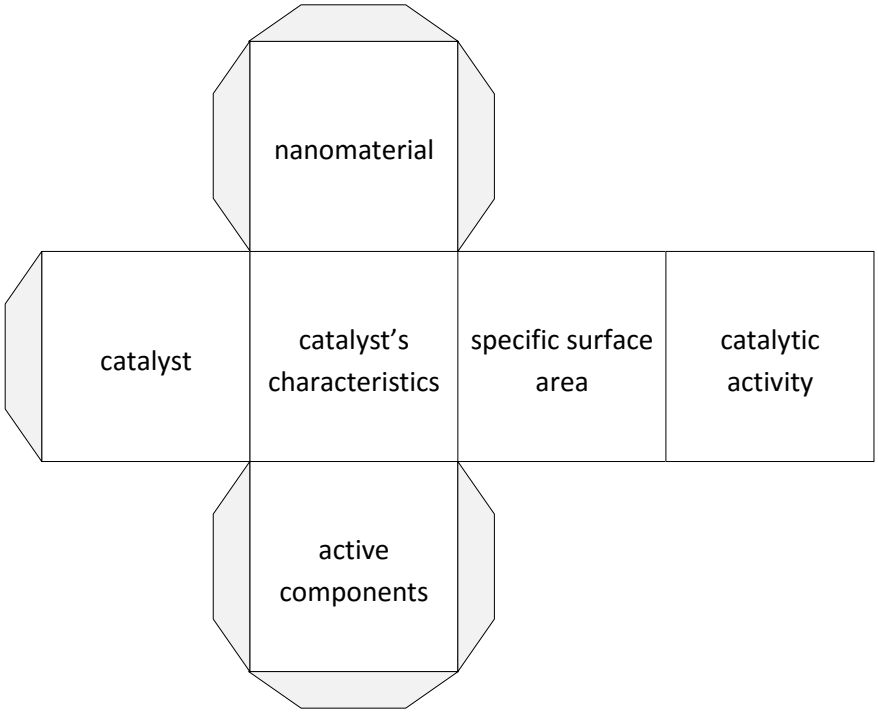


table 7.1.

Example of a student's knowledge self-assessment after the lesson No. 7: *A Catalyst*

Topic: *A Catalyst*	With substantial help from the teacher	With help from the teacher	Independently
1. I can define and explain the term 'siltering'			
2. I can introduce the concept: active catalytic centre			
3. I can explain how temperature affects the crystal size (nanoparticles)			
4. I can plan and carry out demonstration experiments examining the catalytic activity of nanomaterials			
5. I can specify typical features of a good catalyst			
6. I can identify the dependent, independent and controlled variables of an experiment scheduled by myself examining the catalytic activity of nanomaterials			
7. I can demonstrate the dependence between the size of a specific surface area, the number of walls and corners and the activity of the catalyst, and between the application of the roasting process and the size of a specific surface area			

Additional literature

Martin Hermanek, Radek Zboril,* Ivo Medrik, Jiri Pechousek and Cenek Gregor: *Catalytic Efficiency of Iron(III) Oxides in Decomposition of Hydrogen Peroxide: Competition between the Surface Areaand Crystallinity of Nanoparticles*, J. AM. CHEM. SOC., 2007, 129, pp. 10929-10936.
Chunwen Sun, Hong Li and Liquan Chen: *Nanostructured ceria-based materials: synthesis, properties, and applications*, Energy Environ. Sci., 2012, 5, pp. 8475–8505.

At the end of the lesson a teacher might ask students:

What have you learned by conducting experiments at today's meeting?

Where in everyday life is the catalytic activity of nanomaterials used?

8

A Diesel or a Gas/ Petrol Car?

Lesson No.8

A Diesel or a Gas/Petrol Car?

Learning objectives:

- **Making the students familiar with the methods of removing soot from diesel engines exhaust fumes: DPF filters, afterburning using oxide catalysts;**
- **Developing the skills of conducting a discussion, presenting arguments.**

Learning outcomes:

A student is able to:

- **present and discuss the pros and cons of various energy sources/fuels,**
- **participate in a discussion about some problems: How to utilize catalysts? What does an environmentally-friendly catalyst mean?**

Time: 45-60 minutes

1. Engage (Introduction)

1.1 State a problem (Fig. 8.1)

Fig. 8.1 (Author: Mario Beauregard / Fotolia)

1.2 Methods of elimination of soot particles – presentation

The currently used method for elimination of soot particles from diesel engines off-gases is the use of DPF (Diesel Particulate Filters, Fig. 8.2) that help to reduce the amount of soot particles emitted by up to 90%. However, in order not to become clogged by the particles, such a filter needs to undergo 'regeneration cycles' – which is an expensive process from the perspective of car users.

Fig. 8.2: Diesel Particulate Filter (Author: mipan / Fotolia)

2. Explore

2.1 Discussion

T: In what other way can soot be removed from car exhaust fumes?
S: It's mostly carbon – through burning.
T: What combustion process do we mean here? (a question based on the knowledge obtained during previous lessons).
S: Complete combustion, the product of which is CO_2.

2.2 Search on the Internet/literature

T: Find in the literature/internet in what circumstances soot (carbon) burns, creating CO_2 e.g. Juhun Song, Mahabubul Alam and André L. Boehman, CHARACTERIZATION OF DIESEL AND BIODIESEL SOOT (https://web.anl.gov/PCS/acsfuel/preprint%20archive/Files/49_2_Philadelphia_10-04_1144.pdf)
S: For spontaneous ignition and continuation of the combustion process, soot requires a temperature exceeding 500°C.
T: Compare it with the temperature of the exhaust gases from a diesel engine, which is in the range of about 150-400°C e.g. U.S. Department of Agriculture Forest Service, Diesel Exhaust Emission System Temperature Test, http://www.fs.fed.us/t-d/pubs/pdf/08511816.pdf
S: The required temperature is higher.
T: Do you know any method that simplifies and accelerates chemical reactions?
S: The use of a catalyst.
T: Let's examine it then.

2.3 Experiment 8.1 Examining the activity of iron(III) oxide in soot combustion reaction (guided inquiry)

The purpose of this experiment is to examine in the school environment the rate of soot removing process with and without the use of iron(III) oxide as a catalyst. As in real scientific research, toner for laser printers/photocopiers can be used as model soot present in off-gases (the substance under the trade name PRINTEX 80).

2.3.1 Planning

Precautions:
Printer toner – avoid inhaling dust.
Disposal of residues: substances remaining in the water should be drained off and moved to a container for solid flammable waste.

Green colour – possible students' ideas

Research question: Does the use of iron(III) oxide affect the process of soot burning?
Hypothesis: 'Soot with the addition of iron(III) oxide burns faster/slower.' Or 'Iron(III) oxide does not affect the process of soot burning.'
Planning the experiment: In the school environment, the process of soot burning may be performed in a crucible/melting-pot. The amount of soot shouldn't be higher than 0.01 – 0.02 g, as it affects the time of the process.
Determining variables: independent variable – presence/absence of Fe_2O_3 dependent variable – the amount of soot that remained after the experiment /has been burned controlled variables - time, temperature
Description of subsequent steps: e.g. Mix and grate samples of soot of a specific weight with a sample of Fe_2O_3 in a mortar (which helps to increase the interface of both substances). Place the mixtures in crucibles and heat them over a burner for particular time e.g. 1st – 25 min., 2nd – 40 min., 3rd- 55 min. (Fig. 8.3b). Repeat the procedure without the use of Fe_2O_3. To find out how much soot has been burned, pour the crucible's content into a beaker filled with water. Iron(III) oxide falls to the vessel's bottom, and the potential unburned soot remains on the surface as shown in the picture (Fig. 8.3c)

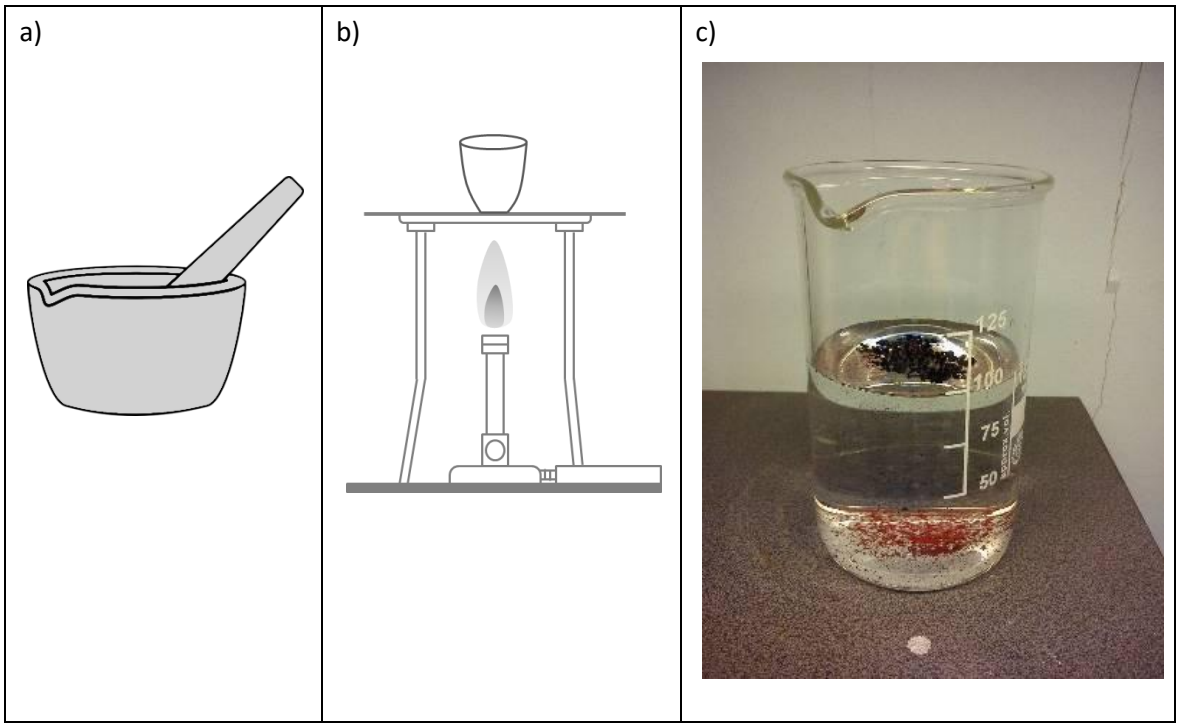


Figure 8.3c: Separation of soot and iron(III) oxide (Photo: Paweł Broś)

2.3.2 Conducting an experiment

Students should check their proposed answers to the research question (assumptions) by comparison with the results of the experiment.

2.3.3 Analysis of the results and an attempt to answer the question: What amount of soot has been removed in the presence of a catalyst?

Students present and discuss the results and conclusions with other groups answering the questions:

- What similarities and differences are there between the results and conclusions obtained by various groups? How did they arise?
- Is the hypothesis confirmed or disproved?
- Have you obtained an answer for your research question?

2.3.4 Discussion of the results and the problem associated with forming conclusions with other groups.

3. Explain

Becoming acquainted with the text discussing the innovations developed at the Faculty of Chemistry of the Jagiellonian University 'Iron Catalyst for Afterburning of Soot Particles' – published in *Innovation Compass* (Fig. 8.4)

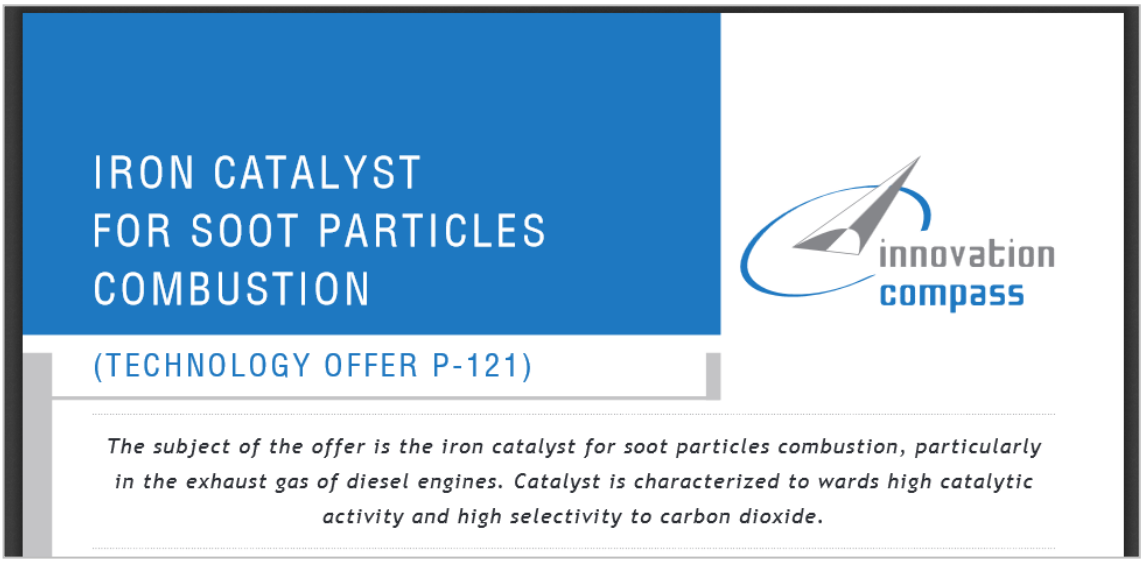


Figure 8.4: Innovation developed at JU (Source: http://www.cittru.uj.edu.pl/documents/1587933/d2fd4ed2-17b7-420d-a604-b599826adce2)

4. Extend

4.1 Introduction to the topic: Innovations in the automotive industry

Man has always wanted to move faster and further than his own feet allow him to and, above all, to transport goods in a different way than on his own back. Initially, man used draught animals (oxen, donkeys, horses) for this purpose, and at some point in history people started to use technological achievements – the wheel, and then the engine converting chemical energy into a mechanical one.

In the days when petrol was used as a cleaning agent, and reciprocating engines were used in industrial factories only, a group of visionaries was working on developing the world's first vehicle powered by an internal combustion engine.
The Maybach-Daimler duo, in 1886, as the first in the world, created a four-wheeled car using to drive a high-speed internal combustion engine. But they were not the only engineers who wanted to create a machine - later called a car. At the same time, Karl Benz was working on a similar invention. In the patent office, his vehicle was called 'Benz Patent-Motorwagen Nummer 1'.

- Diesel cars: Is it time to switch to a cleaner fuel?
  http://www.bbc.com/news/business-33254803
- Gas vs. diesel vs. hybrid: Which car engine is best for you and the environment?
  http://www.extremetech.com/extreme/170763-auto-tech-gas-vs-diesel-vs-hybrid-which-is-best-for-you-and-the-environment
- To diesel or not to diesel? Pros and cons of diesel vs. gas
  http://driving.ca/volkswagen/golf/auto-news/news/to-diesel-or-not-to-diesel-that-is-the-question

4.1 Discussion with students

T : How does the development of the automotive industry affect people and the environment? – Justify your answer providing examples (*Note: It is worth asking about both the negatives and positives; the answer should not be limited to either positive or negative aspects only*)

S: First associations:

- Facilitating the transfer and transport of goods,
- Experience: 'adrenaline' (races), entertainment,
- Sign of prestige,
- Pollution: Exhaust gases containing nitrogen oxides, unburned hydrocarbons, CO, and in the past also lead compounds, rubber abraded from used tires,
- Waste: Scrap, electronics, tyres,
- Car accidents.

T: What actions (innovations) are implemented to reduce the negative aspects of the automotive industry? – Discussion based on the students' general knowledge

S:

- The so-called unleaded petrol (i.e. without the addition of tetraethyl lead – an anti-knock agent);
- Catalytic converters.

4.2 Information from the teacher (or possibly a multimedia presentation)

- In the vehicles with spark ignition engines (petrol, gas and ethanol ones) trifunctional catalysts – TWC (*Three Way Catalyst*) – are used which oxidise hydrocarbons and carbon monoxide (II) to carbon monoxide (IV) and water while reducing nitrogen oxides (NOx) to nitrogen and oxygen. In the vehicles with diesel engines (that burn diesel fuel), CxHy and CO are oxidised, but it is not possible to reduce NOx.
- Direct injection system (directly into the cylinder) in the vehicles with diesel engines has reduced fuel consumption and improved other ecological aspects, but it has not limited particulate emissions enough (carbon black – black fumes that can be observed behind a car), appearing in large quantities with increasing load.

4.3 Discussion with students

T: Considering the above, what should the direction of research and innovation be?
S: The removal or prevention of NOx and carbon black formation in diesel engines.
T: To remove carbon black from the engines, diesel particulate filters (***DPF***) have been used, and to remove NOx – a selective catalytic reduction system (***SCR***) that uses the so-called AdBlue technology (diesel exhaust fluid – DEF)

4.5 Working in groups with the texts (each group receives only one of the texts)

a) Volkswagen – the 'dieselgate' scandal:

Guilbert Gates, Jack Ewing, Karl Russel and Derek Watkins, Explaining Volkswagen's Emissions Scandal. (2016). *The New York Times*, retrieved from: http://www.nytimes.com/interactive/2015/business/international/vw-diesel-emissions-scandal-explained.html?_r=0

Richard Westcott. VW cars can also cheat European emissions tests, BBC learns. (2015)BBC News, retrieved from: http://www.bbc.com/news/business-34857404

b) Particulate filter:

Stoke-on-Trent garages 'illegally remove car emissions filters'. (2014), BBC News**,** retrieved from: http://www.bbc.com/news/uk-england-stoke-staffordshire-29662760

Diesels illegally pumping out pollutants after garages remove filters designed to cut emissions. (2015). *The Independent*, retrieved from: http://www.independent.co.uk/life-style/motoring/motoring-news/diesel-cars-illegally-pump-out-dangerous-pollutants-after-garages-remove-filters-designed-to-cut-a6689191.html

4.6 Discussion with students:

T: What did the inappropriate behaviour/actions of the persons in the texts consist of? In your opinion, what was the reason for such behaviour?

4.7 Group work – preparing a carpet of ideas that represent the answers to the following question: How should/can we prevent such practices?

Several **aspects of RRI** relating to innovations, fuels and catalysts can be mentioned and considered here:

- Is every innovation positive?
- How can it be evaluated?
- Should we continue the research in order to find alternative fuels and, if so, why? How should such research be conducted?
- Should there be standards limiting vehicle emissions, and thus in a way imposing on some citizens which cars they are allowed to drive?
- Should the results of the studies e.g. comparing CO_2 emissions of various car models, be available to the public and, if so, where should they be presented?

5. Evaluate

5.1 In the shops we can buy an agent used to ‘burn the soot’ in home furnaces and fireplaces, containing copper(II) sulphate(VI) pentahydrate.

Source: http://ezakupy.tesco.pl/pl-PL/ProductDetail/ProductDetail/2003012361822

Below there are presented a few sentences from the manufacturer's leaflet, describing several features of this product. Determine whether they are true or false, marking **T** when the sentence is true, **F** when it is false, and **?** when you are unable to decide based on the information provided.

	T/F
It eliminates air pollution with soot	
It eliminates the necessity of mechanical furnace cleaning	
As every millimetre of the residue (cinder, soot) on the furnace's wall increases the consumption of solid fuels by 10%, the use of the agent improves the efficiency of a furnace, fireplace	
It reduces the emission of gases into the atmosphere	
It reduces the corrosion of iron furnace elements	
It reduces dust	

5.2 Below are listed the toxic equivalence factors for the most common pollutants coming out from the X heat source based on the applicable Ordinance of the Minister of Environment of 5 December 2002 on reference values for some substances in the air (Journal of Laws No. 1/2003, Item 12):

SO_2 – 1.00	*NO_x – 0.75*	*Dust – 0.75*	*Soot – 3.75*

Suggest two ways to remove the component that is characterised by the greatest toxic equivalence factor. To do this, briefly describe what each of the proposed methods consists of.

table 8.1

Example of a student's knowledge self-assessment after the lesson No. 8: *A Diesel or a Petrol Car?*

Topic: *A Diesel or a Petrol Car?*	With substantial help from the teacher	With help from the teacher	Independently
1. I can explain the methods of removing soot from diesel engines' exhaust fumes: DPF filters, afterburning using oxide catalysts			
2. I can identify dependent, independent and controlled variables of the experiment examining afterburning of soot			
3. I can identify reliable sources of literature on the dangers of vehicle exhaust emissions			
4. I can present and discuss the pros and cons of various energy sources/fuels			

Additional literature

Juhun Song, Mahabubul Alam, André L. Boehman, Unjeong Kim: Examination of the oxidation behavior of biodiesel soot, *Combustion and Flame,* 2006, 146, pp. 589–604.

At the end of the lesson the teacher might ask the students:

What have you learned by conducting experiments at today's meeting?

In which situations in everyday life can you use information acquired today?

9

Introduction to Photocatalysis

Lesson No.9

Introduction to Photocatalysis

Learning objectives:

Teaching and educational:

- **Making the students familiar with the concept of photocatalysis;**
- **Making the students familiar with selected properties of nanoparticles (in particular TiO_2);**
- **Developing the information research skills, asking research questions, planning and parameterisation of quantitative experiments and performing experiments.**

Learning outcomes:

A student is able to:

- **plan and carry out model experiments illustrating the photocatalysis phenomenon,**
- **discuss selected properties of TiO_2,**
- **discuss the pros and cons of covering surfaces with nanoparticles.**

1. Engage (Introduction)

1.1 Task:

The K1 skyscraper, referred to as 'Błękitek' (Krakow), is 105 m high. It is built on a square plan with the length of the sides of 50 m. The entire facade of the building is covered with glass. Calculate the cost of washing the facade of the building if 1 employee is able to wash 1 m^2 of the facade within 5 minutes and the cost of his work amounts to PLN 75 per hour.

Worksheet 1

Figure 9.1 The Blue Skyscraper (Photo: Michal Łepecki/Agencja Gazeta)

1.2 Involving questions:

- What can be done to save money and keep the windows clean?
- How to reduce the use of detergents and their negative impact on the environment?

Comment:
Students may look for answers to the questions on the Internet. They should find such phrases as: self-cleaning windows, photocatalysis, photoactivity, TiO_2, titanium oxide, hydrophilic properties and UV radiation.

1.3 Teacher's presentation of the experiments

Worksheet 1

Experiment 9.1 Photocatalytic decomposition of 2,6-dichlorophenolindophenol by TiO_2in the presence of glycerol and UV light

Reagents:

- 2,6-dichlorophenolindophenol, sodium salt(DCIP), solution at the concentration of 0.5 g/dm^3,
- Glycerol 99%,
- Titanium oxide with a particle size of ~20 nm.

Examining the activity of TiO_2 in test tubes. Prepare the mixtures:

1. Photocatalytically active solution: 5 cm^3 of DCIP, 0.5 cm^3 of glycerol, a pinch of TiO_2 (approx. 10 mg).
2. Control solution 1: 5 cm^3 of DCIP, 0.5 cm^3 of glycerol, a pinch of SiO_2 or Al_2O_3 (approx. 10 mg).
3. Control solution 2: 5 cm^3 of DCIP, 0.5 cm^3 of glycerol.

Expose the solutions to sunlight for about 10 minutes or use a UV lamp.

Experiment 9.2 Photocatalytic decomposition of 2,6-dichlorophenolindophenolon a self-cleaning windowpane

Mix 5 cm^3 of DCIP and 0.5 cm^3 of glycerol. Place rubber bands on the surface of an ordinary windowpane and a windowpane coated with a photocatalytically active layer. Add the prepared solution drop by drop to the area outlined by the bands. Expose to the sunlight or the light of a UV lamp for approx. 15-30 min.

2. Explore

2.1 Students' task

Worksheet 2

You can use the reagents and equipment presented during the lesson and in addition:

1. Titanium oxide crystallites larger than 70 nm, various polymorphs of titanium dioxide with a size of ~20 nm.
2. Different sources of light (UV lamps, fluorescent lamps, incandescent lamps, daylight, LEDs of various colours).

1.4 Common laboratory reagents

Plan an experiment in which you will investigate the impact of selected factors on the course of one of the processes presented during the lesson. Prepare a research question, formulate a hypothesis and the scheme of the experiment's realisation. Suggest the form of gathering and presenting the results.

Comment:
1.0. The teacher creates a closed working group on Facebook. The students work in groups on preparing the experiments, exchange ideas and ensure that they do not copy each other in their work.

1.1. Potential research problems:

i. *Photocatalytic activity depending on the type of light source(UV lamps, fluorescent lamps, incandescent lamps, LEDs, daylight);*
ii. *Photocatalytic activity depending on the type of the TiO_2 particles size. (TiO_2 20 nm, TiO_2 70 nm, preparations prepared by sintering of commercial substrates);*
iii. *Are both sides of the windowpane active in the same way?*
iv. *Does the position of the light source matter (behind and in front of the window-pane)?*
v. *Photocatalytic activity depending on the type of light source;*
vi. *The impact of pH on the process (acid rain simulation).*

table 9.1.

Example of a student's knowledge self-assessment after the lesson No. 9: *Introduction to photocatalysis*

Topic: *Introduction to photocatalysis*	With substantial help from the teacher	With help from the teacher	Independently
1. I can define the concept of photocatalysis			
2. I can plan and carry out model experiments illustrating the photocatalysis phenomenon			
3. I can specify selected properties of nanoparticles (in particular TiO_2)			
4. I can discuss selected properties of TiO_2			

10

Photo-catalysis

Lesson No.10

Photocatalysis

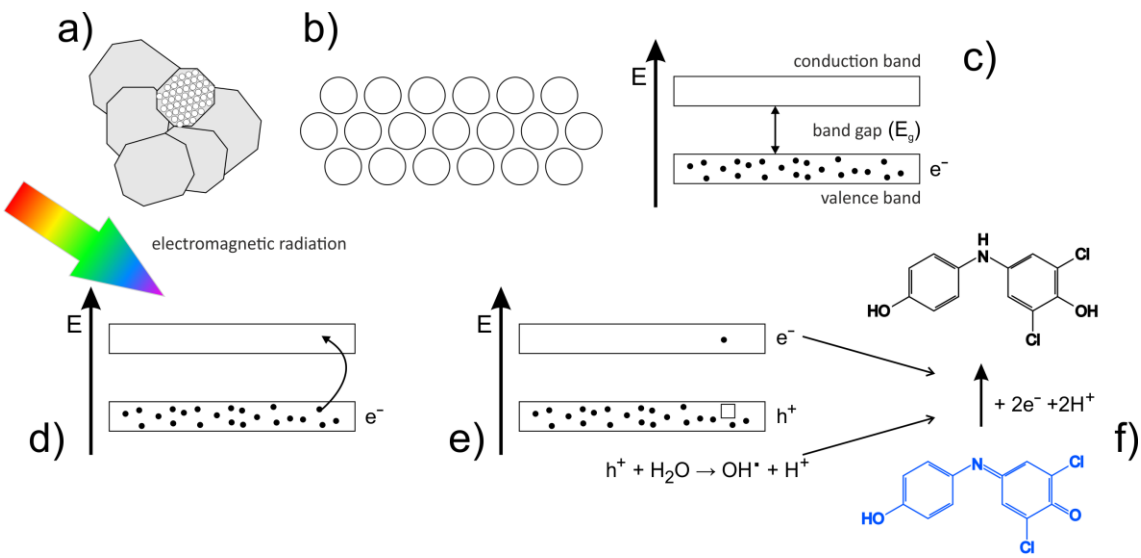
[chapter intro text]

1. Explore

Carrying out the experiments prepared by the students

2. Explain

Discussing the theoretical basis of the DCIP photocatalytic decomposition process



a) Semiconductor material with photocatalytic properties (e.g. TiO_2) exists in the form of nano-size crystals; the crystals may be in an agglomerated form.

b) The crystals are characterised by an ordered structure (periodic arrangement of ions in 3D space).

c) The energy of the electrons in the crystalline material can be described using the so-called energy bands (continuum of available energy states). Energy bands originate from the overlapping orbitals of atoms/ions forming the crystal, just as the molecular orbitals originate from the overlapping orbitals of the atoms forming the molecule. The valence band is formed from atomic orbitals on which valence electrons are located. The conduction band is formed from the empty orbitals with the energy greater than the one of the valence orbitals. In the ideal crystal, energy bands are separated on the energy scale by a gap in which there are no energy states available for the electrons.

d) Under the influence of electromagnetic radiation, with the energy equal or higher of the band gap width, the excitation of an electron (e^-) from the valence band may occur.

At the same time, the so-called electron hole (h, positively charged) in the valence band is formed. Both the electron in the conduction band and the electron hole in the valence band are mobile and they are the charge carriers.

e) As a result of the interaction of electrons or electron holes from the photocatalytic material with the molecules present in the system, the oxidation-reduction reactions may take place. In the case discussed, the glycerine (glycerol) present in the system is oxidised, while the coloured compound of DCIP (blue in the oxidised form) undergoes reduction. In the reduced form DCIP is colourless, while in the partially reduced form it is pink.

f) In general, the suspensions of TiO_2 powder in water show higher photocatalytic activity than such particles deposited on a flat surface. The microparticle-derived films, in turn, demonstrate greater photoactivity than smooth nanoparticles thin films. It is probably related to the surface area of the materials available for the reaction.

4. Extend

4.1 Hydrophilic properties of self-cleaning glass

The materials related to the field of self-cleaning coatings can be divided into two categories: hydrophobic and hydrophilic ones. These two types of coatings are cleaned under the influence of water: the former by removing water by rolling the droplets and the latter by thorough rinsing the surface (sliding motion), which results in the dirt removal. Hydrophilic coatings, however, have an additional property: they can decompose chemically the dirt adsorbed on their surface under the action of the sun.

The self-cleaning property of hydrophobic coatings is due to their high water wetting angles; the water on those surfaces creates almost spherical droplets that roll easily, taking the dust and dirt away with them. The dirty water striking the hydrophobic coating will be removed before it evaporates. The rolling motion of water droplets cleans the surface more effectively, and in such a case leaving of the dirt is less probable than in the case of a sliding motion. Superhydrophobic, or in other words ultraphobic surfaces, occur more frequently than the hydrophilic ones in the world of nature: there are over 200 known species of plants that use water droplets rolling for self-cleaning. Perhaps the most popular plant of such type is the lotus from South-East Asia.

For a macroscopic size droplet placed on a textured (uneven) hydrophilic surface in micro scale, it is advantageous to adapt to the contours of the surface, falling down and spreading as compared to falling on a smooth surface only. Therefore, increasing the roughness of the hydrophilic surface reduces the water drop water wetting angle. On the uneven hydrophobic surface an opposite effect will be observed: it is energetically unfavourable for water to track the shape of the surface, and thus the droplets move away, forming an even greater wetting angle than on a smooth surface.

An example of a synthetic superhydrophobic surface may be a 2 µm thick layer of vertically arranged, non-tangled carbon nanotubes in the form of a 'forest'; a highly textured micro scale surface. Next, the 'forest' is coated with a very thin layer of polytetrafluoroethylene (PTFE). As a result, the surface texture is maintained and the material obtains super hydrophobic properties.

Photocatalytic hydrophilic coatings differ from hydrophobic ones in the fact that their activity is not based solely on the flow of water that washes away the dirt. The coatings are able to chemically decompose the particles under the impact of light– mostly organic – that form the dirt. The materials having such properties are covered with a thin, often transparent layer of titanium oxide (TiO_2), which cleans the surface using sunlight by two different mechanisms. The first, photocatalytic one, makes it possible for the coating to chemically decompose the organic dirt adsorbed on the surface. The other mechanism is based on the inflow of water in the form of 'sheets' rather than droplets due to the hydrophilicity of the surface.

Thanks to the use of sunlight, TiO_2 it is not only one of the most efficient photocatalysts but it also changes its state to a superhydrophilic one. A superhydrophilic state is a state caused by the absorption of light and associated creation of electron/electron-hole pairs. The resulting electron holes modify the properties of the TiO_2lattice oxygen around the surface (reducing it), thus generating oxygen vacancies. Such vacancies (unfilled positions in the crystal) may be filled by water molecules present in the environment, with the formation of hydroxyl groups that increase the affinity of the surface to water – they increase the 'wettability' of the surface.

Titanium oxide is considered to be non-toxic and chemically inert in the absence of light, as well as relatively cheap and easy in terms of processing and related application in the form of thin layers. It is widely used as a white pigment in cosmetics and paints, as well as a food additive.

Although most studies of semiconductor self-cleaning coatings are focused on TiO_2 irradiated with UV light, other materials and methods may be also be potentially applied in the field. Some metal oxides and sulphides, including WO_3, ZrO_2, ZnO and CdS or *polyoxometalates* are being tested as photocatalytic materials, but none of them is activated by light as efficiently as TiO_2.

References

Ivan P. Parkin, Robert G. Palgrave, J. Mater. Chem., 2005, 15, pp. 1689–1695, Self-cleaning coatings.

4.2 Toxicity of TiO_2 nanoparticles

Nanoparticles of oxide materials such as TiO_2 or ZnO are used as additives to toothpastes, cosmetics, creams, sunscreens and textiles. Silver nanoparticles are often increasingly used as antibacterial additives to detergents, food packaging materials and textiles.

As is generally known, the properties of nanomaterials differ from that of micro- and macroscopic materials. This is mainly due to the increased surface area and reactivity that in turn may lead to the increased uptake into cells and the associated toxicity. The properties of the nanoparticles surface also determine their stability and mobility in colloidal systems and dispersions, and they influence the aggregation into larger particles and depositing as such in aqueous systems. Such agglomerated particles in aqueous systems which are subject to sedimentation may be seen as a significant sink, a mechanism for the neutralisation of synthetic nanoparticles.

The toxicity of nanoparticles is not always greater than the toxicity of microparticles. The property is not general and it is highly dependent on the type of nanoparticles (chemical composition), morphology (crystallites shape) and related surface characteristics.

Oxidative stress due to the presence of nanoparticles, whether they are natural or synthetic, is one of the main mechanisms associated with their impact on living organisms. Oxidative stress occurs when the created reactive oxygen species upset the balance in cells in which there is a reducing environment. Reactive oxygen species may be formed by radicals, transition metal compounds or other chemicals by their interaction with different cellular components. For example, mitochondria are attacked by the particles which have been phagocytosed by the cells. Mitochondria are also the sources of formation of reactive oxygen species. Mitochondrial damage can lead to the increased production of reactive oxygen species and a reduction in mitochondrial membrane potential and apoptosis.

In the macroscopic scale, the toxic effect of nanoparticles can be manifested by the increased occurrence of respiratory system diseases, cardiovascular diseases and increased mortality of people with prolonged exposure to nanomaterials such as TiO_2, carbon nanoparticles (soot) or silica (SiO_2), and many materials of natural origin. However, such an impact is not clearly scientifically proven, and the most important recommendation is to avoid taking in (e.g. by inhalation, oral or dermal absorption) of substances containing nanoparticles at a high concentration. It should be noted that although nanoparticles are toxic to living organisms, including humans, it does not exclude their usefulness.

The skin may be exposed to the adverse effects of nanoparticles through the intentional use of substances containing them, such as creams or lotions containing nanometric TiO_2 or ZnO, and textiles coated with substances that improve their hydrophobic, anti-fouling or anti-bacterial properties. Non-intentionalcontact may be caused by the exposure to the environment where nanoparticles formed as a result of the production of nanomaterials (e.g. oxide ones), or resulting from the combustion of the matter (e.g. soot) occur.

It has not been evidenced conclusively whether and to what extent nanoparticles penetrate the skin and whether there have any toxic effect there. A number of effects related to the

possible penetration of the skin by nanoparticles are examined: 1) toxicity to the skin or other organs, 2) accumulation in the skin and other organs leading to toxicity associated with long-term exposure, 3) distribution to the particles of even smaller sizes resulting in a possible increase in toxicity, and 4) toxicity of nanoparticles activated under the action of light.

References

1. Anne Kahru, Henri-Charles Dubourguier, Toxicology 269 (2010) pp. 105–119, From ecotoxicology to nanoecotoxicology.
2. Hanna L. Karlsson , Johanna Gustafsson, Pontus Cronholm, Lennart Möller, Toxicology Letters 188 (2009) pp. 112–118, Size-dependent toxicity of metal oxide particles—A comparison between nano- and micrometer size.
3. Karla Soto, K.M. Garza, L.E. Murr, ActaBiomaterialia 3 (2007) pp. 351–358, Cytotoxic effects of aggregated nanomaterials.
4. Joyce S. Tsuji, Andrew D. Maynard, Paul C. Howard, John T. James, Chiu-wing Lam, David B. Warheit, Annette B. Santamaria, Toxicological Sciences 89 (2006) pp. 42–50, Research Strategies for Safety Evaluation of Nanomaterials, Part IV: Risk Assessment of Nanoparticles.
5. https://www.youtube.com/watch?v=XecqGni5Wsg

4.3 Additional topics for discussion

- Risks associated with the synthesis of TiO_2
- Lifetime of photocatalytically active coatings
- Other types and properties of nanoparticles-modified glass
- Examples of the above-mentioned technology implementation

Homework

- Students develop the results obtained within a Facebook group
- Design an exhibit on the issues discussed for an exhibition.

6. Evaluation

Task 1. Complete the text or select – by highlighting – the appropriate text in brackets:

a) Photocatalysis, according to the definition by IUPAC, is a .....(catalytic) reaction consisting in the .....(absorption) of light by a photocatalyst or .....(substrate).
b) A photocatalyst is a substance that .....(takes part in) the reaction in the presence of light and (is/is not) consumed during the reaction.
c) An example of a photochemical reaction is the .....(photosynthesis) of sugars with carbon dioxide and .....(water) in .....(leaves) of green plants.

Task 2. Underline all information that is true about a photocatalyst:

- photoactivity
- the ability to use visible and/or UV light
- photostability
- low price
- low toxicity level

Task 3. Determine whether the following statements are true or false by writing the letter T (true statement) or F (false statement):

Titanium dioxide absorbs any length of electromagnetic waves .....(F)
Titanium dioxide absorbs only UV radiation .....(T)

Task **4.** Is it possible to change the contact angle against water on the surface of irradiated titanium dioxide? Justify your answer.

table 10.1.

Example of a student's knowledge self-assessment after the lesson No. 10: *Photocatalysis*

Topic: *Photocatalysis*	With substantial help from the teacher	With help from the teacher	Independently
1. I can define a hydrophobic, superhydrophobic, ultraphobic surface			
2. I can explain the toxicity of TiO_2 nanoparticles			
3. I can plan a simply experiment examining photocatalytically active coatings			
4. I can describe the risks associated with the synthesis of TiO_2			
5. I can identify dependent, independent and controlled variables on an experiment scheduled by myself			
6. I can explain the hydrophilic properties of self-cleaning glass			
7. I can discuss the pros and cons of covering surfaces with nanoparticles			

11

Planning, Preparation, Building and Opening an Interactive Exhibition

Lessons 11-13

Planning, Preparation, Building and Opening an Interactive Exhibition

Through this part and an earlier lesson no.3 about the building exhibition students should develop:

- **understanding of poster, digital poster, book, video, games as exhibits**
- **understanding of the nature of interactive exhibits**
- **understanding of what interactive exhibition mean?**
- **understanding of how to supports the visitor's understanding and knowledge development**
- **understanding of fundamental parts of exhibition building: pre-production, production and postproduction**
- **competences related to the participation in the debate and knowledge of SWOT analysis**
- **skills that support peer – learning**
- **ability to communicate using appropriate language, to stimulate conversations between students and visitors**
- **appreciation of the contribution of visitors and builders of exhibitions**

1. Time devoted to planning and preparation of interactive exhibits

2. Building of interactive exhibition

3. Opening of exhibition

3.1 Proposals for visitors (prepared by students):

the SWOT analysis 'Nanomaterials in the environment': impact of nanomaterials on the environment and use of nanomaterials and nanotechnology in environmental protection.

Teaching note

SWOT analysis is an analytical technique consisting in the segregation of the possessed information on a given issue into four groups:

- ***S** (Strengths) – strong points: anything that is an asset, advantage, good point of the analysed object/situation/solution,*
- ***W** (Weaknesses) – weak points: anything that is a deficiency, barrier, disadvantage,*
- ***O** (Opportunities) – chances: anything that offers a chance for a positive change for the analysed object/solution/action,*
- ***T** (Threats) – hazards: anything that exposes the analysed object to the risk of an unfavourable change.*

The information is then stored in a four-pole matrix. There are three main approaches explaining the differences between the upper half of the matrix and the lower half:

1. *strengths and weaknesses are internal factors, opportunities and threats – external ones;*
2. *strengths and weaknesses are the features of the current situation, and opportunities and threats are the expected future phenomena.*
3. *strengths and weaknesses are the factors dependent on us (the ones that we may influence through our plans and management), and opportunities and threats are objective factors that we cannot influence directly.*

- A debate 'Nanomaterials and Nanotechnology – Benefits and their Limitations' based on 'Nanoparticles – the pros and cons of their occurrence and use' / 'Nanomaterials – are they a threat to us?' – presentations of student groups or on the statements published on the portal:

http://www.nanopinion.eu , http://www.asekor.pl/nanomaterialy.pdf, https://www.youtube.com/watch?v=Yz6LuH-11II

Teaching note

Course of the debate:

- *A few weeks before the opening of the exhibition, the teacher divides (randomly or according to the declared position) the participants into 2 groups (supporters and opponents of the thesis; for and against the use of nanoparticles and nanotechnology in the economy).*
- *Students prepare arguments and evidence on the basis of the proposed and independently found sources.*
- *The debate is a discussion moderated by the teacher or a student. The moderator's tasks include opening the discussion, giving the floor, and taking the floor away, in the event of exceeding the time limit, and supervising whether the standards of discussion are followed.*
- *During the debate, a 'for' party is intended to present the essential theses of their view and provide the best possible arguments supporting it. The 'against' party will refute, challenge and provide counter arguments. The statements of both parties should be short, as concise as possible and formally well-organised. The arguments need to be substantive. The discussion is begun by the 'for' group. The debate moderator makes sure that the representatives of both groups take the floor alternatively, controls the speaking time of particular debaters, and makes sure that all the principles of proper discussion are followed. The first speeches, detailing the opinion of both parties, may be slightly longer (5 to 7 minutes), while the duration of the successive speeches should not be longer than 3-4 minutes.*
- *The debate may be joined in by the audience present at the exhibition opening*
- *In the final phase of the debate there is some time for the speeches summarising both views and presenting the audience's opinions.*
- *We assume that the purpose of the discussions is to reach a compromise - a common ground - and the moderator should ask each group to include in their final statement the view of the opposite group, and thus we get to RRI – constraints in research and innovation.*
- *When closed, the debate should be summarised. If there were factual errors in the students' arguments, they can be corrected now.*

<u>Evaluation</u>

- An observers team may be established, whose task will be to evaluate the debaters. Each person in a team is assigned several people to observe and evaluate. The team works based on the evaluation sheets (below)

Names and surnames of the observed students	Positive behaviour	Negative behaviour
1. …….. 2. …….. 3. ……..	○ Correctness and diversity of arguments and evidence used; ○ Relevance and accuracy when justifying one's view; ○ Language correctness; ○ Attitude (respect for the opponent and following the principles).	○ Straying from the debate subject; ○ Exceeding the time limit; ○ Attacking the opponent himself/herself, and not his/her argumentation; ○ Continuous interruption of the opponent.

12

Evaluation Tools

Generic Competences Evaluation

Evaluation Tools

Different types of assessment are used to ensure that there is progression in learning and to check whether students acquire knowledge and develop their skills and competences. Formative assessment (assessment for learning) is used to assist learning and help learners, based on qualitative feedback. Summative assessment (assessment of learning) is used to summarize and report what has been learned at a particular time (learning outcomes). All assessment techniques can be summative, and only some are formative. In most cases, the assessment criteria should be developed together with students at the beginning of the learning process / activity.

At the end of each lesson being a part of this module there are proposed tasks (tests) included that can be used for the assessment of the students' knowledge and skills directly related to a given topic.

In this chapter (12), the tools have been proposed allowing for the evaluation of general competences, such as team work, communication, inquiry. They mainly include peer- and self-assessment sheets. There are also tools (questionnaires for visitors) included which support the evaluation of an interactive exhibition.

STUDENTS' INTERACTIVE EXHIBITION EVALUATION FORM

1. How would you evaluate various elements of the exhibition? – please evaluate from 0 to 5

Element	Mark					
	0 not present	1 poor	2	3	4	5 very good
Interactive character of the exhibits – Do the exhibits allow for a viewer's independent activity? Do the exhibits help viewers to interact with other viewers?						
Aesthetics (appearance) of the exhibits						
Ingenuity of the exhibits						
Presentation of **modern scientific issues**						
Presentation of the issues concerning **Responsible Research and Innovation** (**RRI**): ethical issues, open access to research results, social participation in the planning and evaluation of research, gender equality in research teams etc.)						
To what extent do the exhibits **combine scientific content and RRI issues**?						

2. Which exhibit did you like most? Please provide the name of the exhibit and briefly justify your choice.

……
……
……

STUDENT WORK OBSERVATION SHEET (INQUIRY SKILLS)

Name and surname: **Date:**

Skills and attitudes	**Student:**	**Always**	**Often**	**Some-times**	**Never**
planning	is able to plan an experiment, poses appropriate research questions, defines the variables				
conducting the experiment	takes an active part in carrying out the tests, documents the experiments' results in an appropriate way, follows the safety rules in a chemical laboratory				
reasoning	draws proper conclusions based on the data collected				
argumentation	presents the conclusions to the rest of the group				

GROUP WORK OBSERVATION SHEET

Scale:
2 –yes/often
1 –hard to define/sometimes/partially
0 –no/rarely

Cooperation – competence elements:	Evaluation (mark) or description of the observation result
1. The group actively participates in the classes	
2. There is a productive work environment in the group	
3. The members of the group shared the tasks	
4. Everyone performs his/her own task	
5. The members of the group assist each other	
6. The members of the group observe the principles of appropriate discussion, respect the opinions of others and use constructive criticism	
7. The members of the group share the results of their reflections or studies with each other	

PEER-ASSESSMENT CARD FOR THE ASSESSMENT OF WORKING COLLABORATIVELY

Peer-assessment card	Peer 1	Peer 2	Peer 3
1. Did your colleague take part in carrying out the given tasks?			
2. Did your colleague help the group?			
3. Did your colleague take part in			
4. Did your colleague communicate properly in the group?			

Peer-assessment card

Source: http://results.sails-project.eu/units/electricity

Evaluation table for working collaboratively (teamwork)

Use the following scale and mark the option which describes you most:	**1** **Almost never**	**2** **Rarely**	**3** **Sometimes**	**4** **Always**
1. I am more comfortable working in a group than working alone.				
2. I like working in a group, because I would not manage the work on my own.				
3. I can listen to ideas of other members of the group.				
4. I learn more during group work.				

Working collaboratively

Source: http://results.sails-project.eu/units/acids-bases-salts

GROUP WORK SKILL SELF-ASSESSMENT

Name and surname: **Date:**

Criteria/frequency	**Often**	**Sometimes**	**Rarely**
I listen to the opinions of other group members, respect them and I take them into account			
I communicate clearly with the others			
I complete the tasks I undertake/am assigned the best I can			
I am flexible and willing to follow others but also take initiative when needed			
I help other group members			
I can persuade the group about my idea.			

I was active in* …… ……..

My two most important strengths in group work (from the list above) are:
1. .....
2. .....

Two skills in group work (from the list above) which I need to work on are:
1. .....
2. .....

***** to be completed for a particular lesson (e.g. in the discussion, searching for information, conducting an experiment)

ASSESSMENT OF AN INDIVIDUAL STUDENT'S CONTRIBUTIONS DURING A BRAINSTORMING ACTIVITY (LESSON PART 2.4 AND LESSON PART 3.1)

Student name	Context – everyday life	Engagement	Creativity	Using scientific words
Name 1				
Name 2				
Name 3				