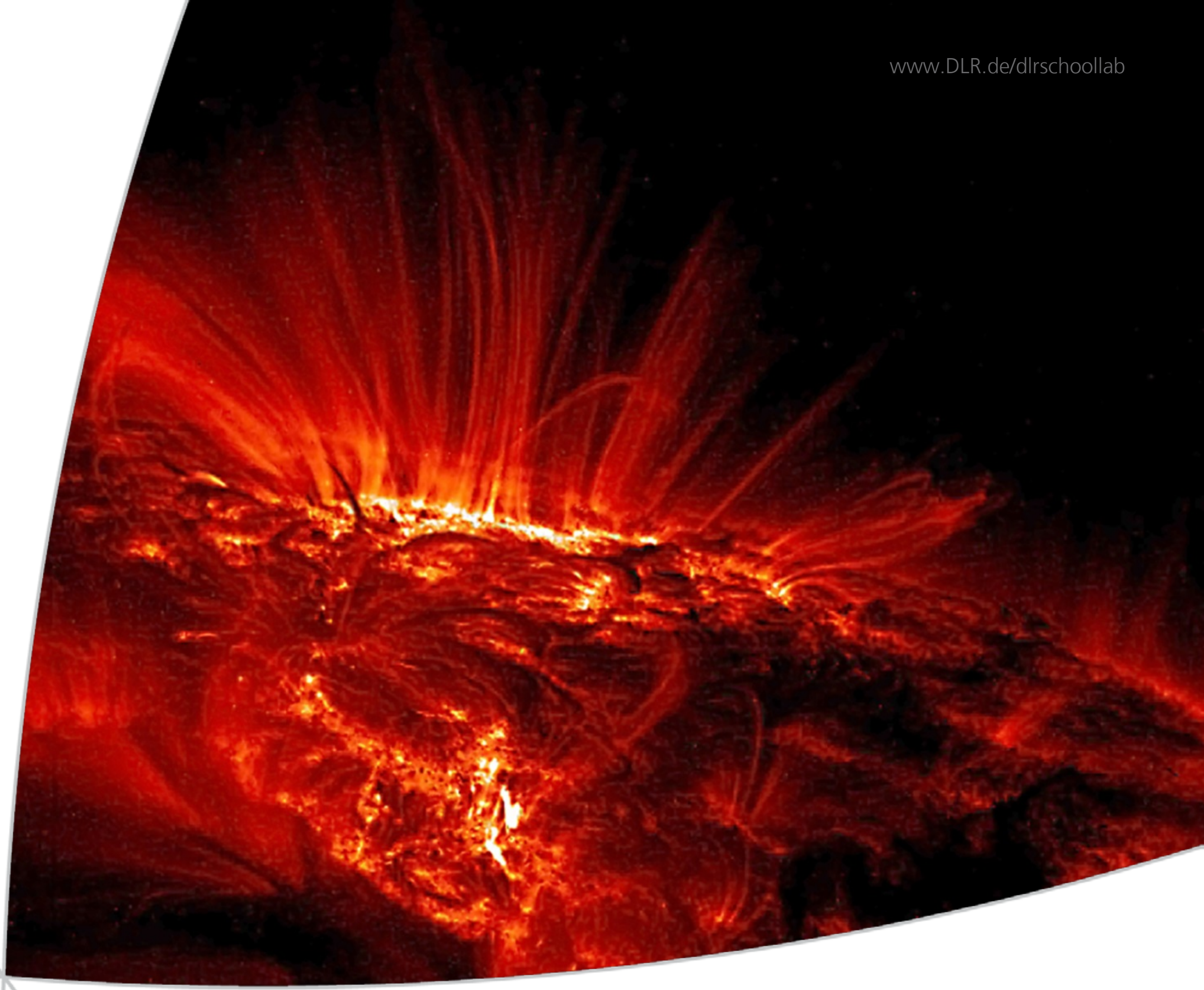


DLR_School_Lab
Köln

Solar water purification

Whenever we use our taps fresh, clean water that we can drink without hesitation flows from them. This is not the case in other parts of the world. Many cleansing processes are necessary in order to turn wastewater back into a drinkable substance.

Wastewater is usually transported to sewage works, where it is first cleansed mechanically, sometimes chemically. The next step is the addition of microorganisms, e.g. bacteria. They consume and break down the pollutants. But they are not able to break up all of our domestic and industrial pollutants. If bacteria cultures die, the entire sewage plant has to be shut down until the population has recovered.

Different methods are employed to reduce the amount of pollutants in wastewater: Bonding agents (e.g. activated carbon) are able to absorb harmful substances. However, this procedure introduces new chemicals into the process and does not reduce the pollutants. This experiment will show you a new method that uses solar energy to break down hazardous substances.

Plants have been using solar energy for chemical processes for millions of years. The majority of the world's biomass is dependent on photosynthesis. Mankind has been using solar energy for chemical processes such as bleaching for millennia. However, we have yet to make use of the inexhaustible supply of free solar energy on an industrial scale. This is likely to change soon.

Two main types of photoreactions are currently being used to cleanse wastewater:

Semiconductor photocatalysis

This technique sees a substance reacting with the help of a catalyst. A catalyst is a substance that enables a chemical reaction or increases its rate, while not being consumed by the reaction. Titanium dioxide (TiO_2) can be used as a catalyst. It is a harmless compound that has no adverse effects on the environment. It is included in white paint or tooth paste. You might find it in food, where it is declared as E171. Titanium dioxide is a semiconductor that absorbs the solar energy (hν) in our experiment.

As a result of this, electrons jump to a higher energy level. Because this reaction requires a certain amount of energy, it only works with UV light. The electrons set free by this process (e^-) and the electron "holes" (h^+) function as oxidant and reducer in the ensuing chemical reaction.

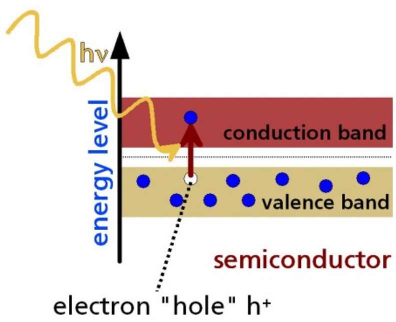
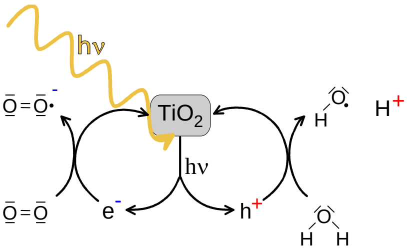


Diagram of the energy- band- model of semiconductors and the excitation through light energy (hν)

Highly active hydroxyl radicals (HO•) that can break down almost any bond are created in this way. Oxygen radicals are generated and react with water to create hydrogen peroxide



Photocatalytic reaction with titanium dioxide

The Photo- Fenton-reaction

Iron (II) or iron (III) compounds are used as catalysts and hydrogen peroxide is also needed. This reaction will work using light from the visible spectrum.

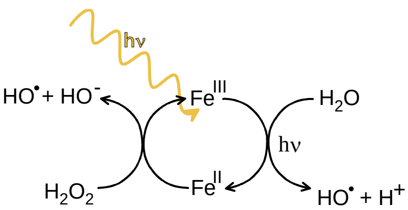


Photo-Fenton-reaction

Our experiment

25l of water will be contaminated using formic acid as a model pollutant. This water will then be purified in our apparatus. We will follow the degradation of the acid as well as the temperature with a pH meter at regular intervals (every minute).

The values we measure for temperature and pH will be plotted in a table and a coordinate system against the time. This way, we can document the degradation of the acid along with changes in temperature.

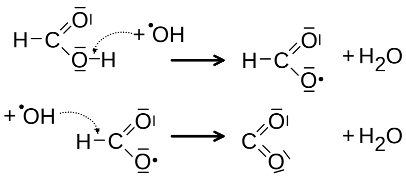
> How will you label the axes?

> How do you expect the curve to progress?

Depending on the weather conditions, we will carry out the experiment outdoors, using sunlight or else indoors with artificial UV light.

Degradation of the model substance

The following chemical equations show the degradation of formic acid.

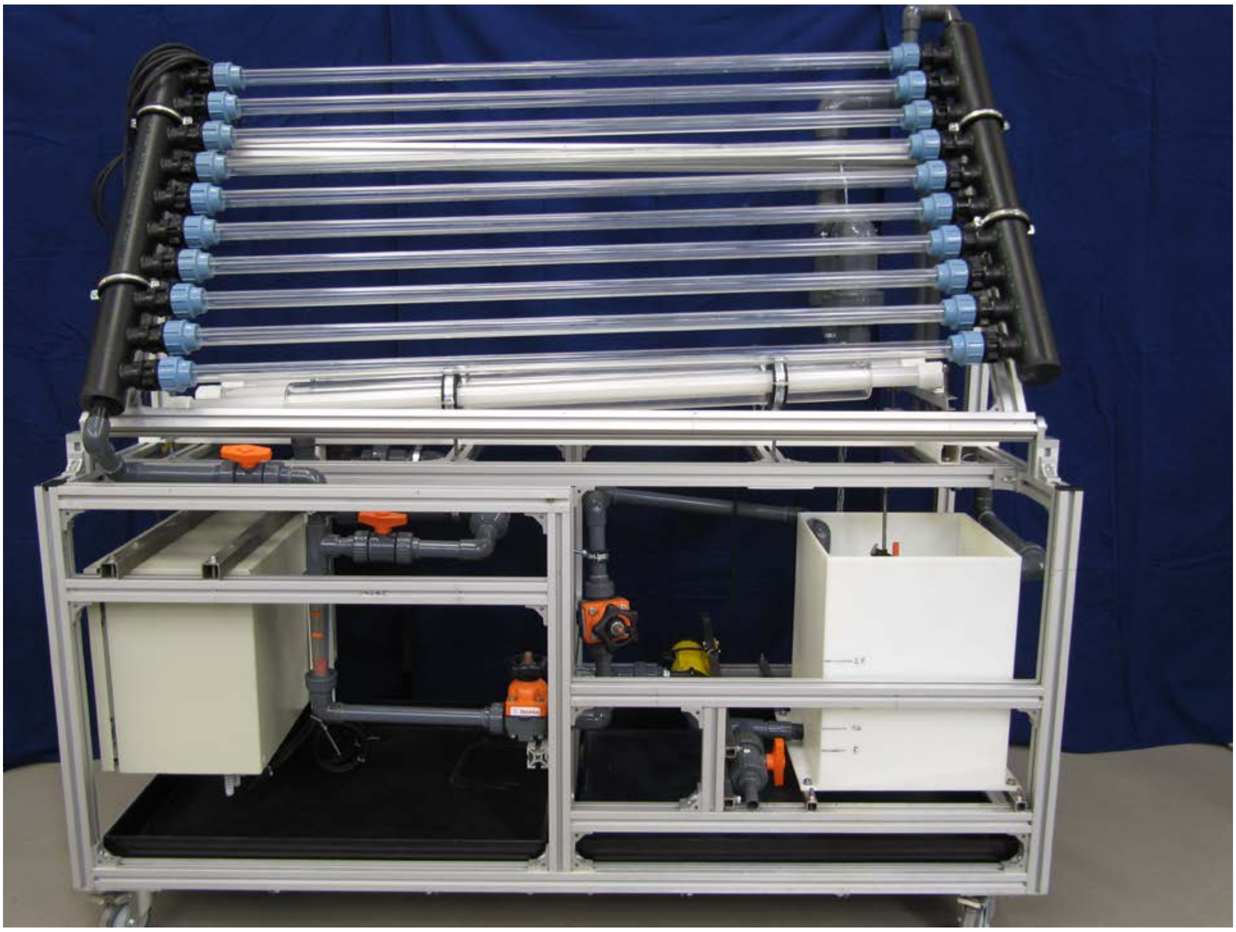


As you can see, the only substances that remain at the end of the reaction are water and carbon dioxide, which are both harmless.

To verify our results, we can conduct a second experiment in which we fill a clear and a blackened glass bottle with our model pollutant and the catalyst, expose both to light and carry out the same measurements.

> What do you expect to see, assuming the reaction only works when exposed to light?

> How might heat influence the reaction?



The apparatus for solar water purification in the DLR_School_Lab Cologne combines two reactors: The ten sloping tubes can be used to carry out the experiment using sunlight. Underneath, three almost horizontal tubes carry the chemicals when artificial UV light is used. The bottom of the apparatus carries (from left to right) a switchboard, valves, the pump (yellow) and tank for the reactants.

Literature

J. Blanco, S. Malato, Solar Detoxification, Natural Sciences, World Solar Programme, UNESCO, 1996-2005 2000.

J. Falbe, M. Regitz, Römpp Lexikon Chemie, Thieme, Stuttgart, 10. Aufl., 1996. - Schlagworte: Photochemie, Photokatalyse

J. Mattay, Von der Laborsynthese zur Solarchemie: Ein Beispiel für nachhaltige Chemie, Chemie in unserer Zeit 2002, 36, 98-106.

H. Kisch, W. Lindner, Synthesen durch Halbleiter-Photokatalyse, Chemie in unserer Zeit 2001, 35, 250-257.

Further reading

http://www.ag-solar.de/ - Die Arbeitsgemeinschaft Solar des Landes NRW

http://www.solarpaces.org/ - Homepage des Solar PACES Implementing

DLR at a glance

DLR is the national aeronautics and space research centre of the Federal Republic of Germany. Its extensive research and development work in aeronautics, space, energy, transport, digitalisation and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation's largest project management agency.

DLR has approximately 8000 employees at 20 locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Bremerhaven, Dresden, Goettingen, Hamburg, Jena, Juelich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Oldenburg, Stade, Stuttgart, Trauen, and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington D.C.

DLR Cologne

Aviation, space travel, transportation, energy and safety are the research areas pursued in the nine research facilities at DLR Cologne. The basis of the research and development carried out on site are the large testing facilities such as wind tunnels, turbine and materials test benches and a high-flux density solar furnace. The 55 hectare/ 136 acre site is home not only to the research and administrative facilities of the DLR, but also to the European Space Agency's (ESA) European Astronaut Centre (EAC). The DLR has around 1400 employees in Cologne.

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About the experiment:

Recommended for grade(s): 8 to 13

Group size: 5 to 6

Duration: 50 minutes

Subject matter:
Chemistry
(Physics)

DLR
Deutsches Zentrum für Luft- und Raumfahrt

DLR_School_Lab Köln

Linder Höhe
D-51147 Köln

Head: Dr. Richard Bräucker
Telephone: ++49 2203 601-3093
Telefax: ++49 2203 601-13093
E-Mail: schoollab-koeln@dlr.de
Internet: www.DLR.de/dlrschoollab

Hinweise zum Experiment:

Jahrgangsstufe: 6 bis 13
Gruppengröße: 5 bis 6
Dauer: 50 Minuten
Inhaltlicher Bezug:
Chemie
(Physik)