

MoDRN Module: Oxybenzone versus Zinc Oxide in Sunscreen for Chemistry Classrooms


Teacher's Notes

This lab is estimated to take 1.5 to 2 hours.

Oxybenzone is used in chemical-based sunscreens as a photoprotective agent against UVB and short-wave UVA rays with an absorption profile from 270 to 350 nm with absorption peaks at 288 and 350 nm. It was allowed for use in 1975, although research shows it to be a possible endocrine disruptor as well as having “high concerns” for biochemical and cellular change impacts due to the production of reactive oxygen species. Some animal studies have also shown development effects at high doses, although studies have been inconsistent in conclusion. A CDC biomonitoring summary indicates that appreciable levels of oxybenzone can be found in urine. The European Commission concluded that there is estrogenicity, although there is no similarity of conclusion from U.S. Agencies. At this time, there is no information on carcinogenicity.

In response to concerns over this molecule found in sunscreens, a substitution of Zinc Oxide was made in many formulas, especially for children as there is a significantly increased potential for harm. Rather than being absorbed, as oxybenzone is (it has been noted to be in potentially 97% of the population as a bioaccumulative), it is relatively inert and does not absorb. There is some difference on opinion whether Zinc Oxide works by reflecting or scattering UV rays or absorbing it and converting it to infrared heat. Zinc Oxide in sunscreen is considered a nanoparticle, and there is some concern in that regard. It is considered non-toxic and a GRAS product (Generally Recognized as Safe), however inhalation of Zinc Oxide should be avoided due to the size of the particle and the negative health impact on the lungs.

This may be approached as a movement across membranes topic. Zinc Oxide has a very low dermal absorption whereas oxybenzone has been shown to be significantly absorbed dermally, although there are some conflicting studies.



The chemistry classroom module aligns to the following Next Generation Science Standard: HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

The biology classroom module aligns to the following Next Generation Science Standard: HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

The environmental science classroom module aligns to the following Next Generation Science Standard: HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity. **NOTE: The experiment for the environmental science classroom can be adapted uses other organisms or seeds.**



Supplemental Readings

The following are supplemental readings for you and your students to understand the general principles of green chemistry as well as the role of molecule substitution in toxicity consideration:

CDC. (2013). Oxybenzone: Biomonitoring Summary. Retrieved from http://www.cdc.gov/biomonitoring/Benzophenone-3_BiomonitoringSummary.html

European Commission. (2001). Opinion on the Evaluation of Potentially Estrogenic Effects of UV-filters adopted by the SCCNFP during the 17th Plenary meeting of 12 June 2001. Retrieved from http://ec.europa.eu/health/scientific_committees/consumer_safety/opinions/sccnfp_opinions_97_04/sccp_out145_en.htm

European Commission. (2006). Opinion on Benzophenone-3. Retrieved from http://ec.europa.eu/health/ph_risk/committees/04_sccp/docs/sccp_o_078.pdf

Environmental Working Group. (2014). Oxybenzone. Retrieved from <http://www.ewg.org/skindeep/ingredient/704372/OXYBENZONE/#>

NCBI. (n.d.). PubChem compound: Oxybenzone. Retrieved from <http://pubchem.ncbi.nlm.nih.gov/summary/summary.cgi?cid=4632>

U.S. Department of Health and Human Services. (2015). Toxicology tutorials. Retrieved from <http://sis.nlm.nih.gov/enviro/toxtutor.html>

Background

What is UV? UV is ultraviolet light, a light wave shorter than violet-color light. UV light is divided into 3 wave-lengths: UV-A, the most common; UV-B, the most dangerous; and UV-C, is dangerous but we're not exposed because it is bounced back to space by the Earth's ozone layer.

THE LIGHT SPECTRUM

Infrared	Visible	UV-A	UV-B	UV-C
1000-700nm*	390-700nm*	400-315nm*	315-280nm*	280-100nm*
Makes our skin feel warm. Can be seen by snakes	Wavelength seen by our eyes. Includes the colors of the visible spectrum	Invisible. Shorter wavelengths, more energy. Causes skin damage, premature aging, melanoma. Passes through car glass	Causes sunburn, skin cancer, photo-aging, cataracts. Needed for Vitamin D synthesis	Dangerous, but completely absorbed by the ozone layer and doesn't reach earth surface

What does Exposure mean?

Exposure happens when UV radiation from the sun reaches your skin. You are exposed to UV when you are outside on sunny or cloudy days. UV intensity varies with time of day, season, and latitude. The equator at noon receives much more UV than at noon in Norway. You can still get sunburned on cloudy days because UV rays can bounce off the clouds. This is known as the broken-cloud effect. In fact, one survey found that UV-B increased by 25% on partly cloudy compared to sunny days.



Risks & Benefits of UV Exposure

UV is an environmental carcinogen, which means that being exposed to UV light can cause cancer. Unprotected UV exposure causes skin damage, speeds aging and increases lifetime risk of skin cancer. Sun exposure also causes wrinkles, brown spots, leathering and sagging. There is no such thing as a healthy tan. Any change in your skin color is a sign of skin damage. 1.3 million people are diagnosed with skin cancer in the US each year, mostly from sun exposure. UV is harmful for anyone, but those with fair skin are at higher risk because they burn more quickly and severely. More Americans have skin cancer than all other cancers combined. The only benefit of UV exposure is Vitamin D. Five minutes of unprotected UV 2-3 times a week provides all the Vitamin D the body can make. Some UV reaches the skin even when you wear sunscreen.




What is SPF?

SPF stands for Sun Protection Factor. SPF is the fraction of UV-B rays blocked by the sunscreen. In SPF15, 1/15th of the UV-B rays will reach the skin when sunscreen is applied properly. If you get sunburned in 10 minutes without sunscreen, you will prevent sunburn for 150 minutes by wearing an SPF15 sunscreen. SPF15 sunscreen protects from 93% of UV-B, SPF30 protects from 97%, and SPF50 gives 98% protection. The Food and Drug Administration (FDA), which regulates sunscreens as an over-the-counter drug, does not recommend using sunscreen with SPF higher than 50. FDA says sunscreen higher than SPF50 is misleading because it offers little added protection, gives a false sense of safety, and tempts people to reapply less often or stay in the sun longer.



What about nanoparticles in sunscreen?



Nanoparticles are ultra-fine particles between 1-100 nanometers in diameter. Nano-size titanium dioxide and zinc oxide have been used in some sunscreens since the 1990s. These physical ingredients reflect, scatter and absorb UV rays and don't tend to cause allergic reactions. The nano-size particles are clear, while older sunscreens used larger particles that appeared white on the skin. Nanoparticles do not pass through healthy skin. Sunscreen with nano-particles protects skin as soon as it is applied while conventional sunscreens must be absorbed.



Risks & Benefits of Using Sunscreen

Sunscreens are more protective against UV-B than UV-A. Avobenzone, titanium dioxide and zinc oxide protect against UV-A. New products that protect against UV-A are used in Europe and are under review by the FDA. Spray sunscreen should not be inhaled, especially sunscreen with nanoparticles because the small particles can be harmful to the lungs. Oxybenzone in sunscreen can penetrate the skin and cause an allergic reaction. It can also interfere with normal hormone function. Sunscreen SPF's higher than 50 have higher concentrations of chemicals and are more likely to have these effects. However, any sunscreen is better for you than being exposed to UV radiation.

How Can I Protect Myself?

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- Stay out of the sun between 10am-4pm
 - Stay in the shade
 - Wear protective clothing
 - Use a "broad spectrum" sunscreen with SPF30-50 to protect from both UV-A and UV-B
 - Avoid getting sunburned
 - Apply sunscreen thickly, 1 oz. every 2 hours
 - Apply conventional sunscreen 20 min. before going in the sun, giving it time to absorb into your skin
 - Don't use indoor tanning beds. Exposure to tanning beds before age 30 increases the risk of developing melanoma by 75%
 - With less mature skin and higher surface area to body weight, babies should not be exposed to UV or sunscreen. Babies under 6 mo should be covered and kept out of the sun, especially from 10am-4pm
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Student Laboratory Experiment: UV Analysis of Sunscreens Using Spectrophotometry

Student Learning Objectives

At the end of this lesson, students will be able to:

- Predict the differences between the various SPF levels
- Use a spectrophotometer to analyze absorption of various sunscreens
- Analyze the data to confirm or contradict predictions made about the various SPF levels
- Use a graph to determine absorption patterns at various wavelengths.
- Dilute a stock solution
- Understand health differences between zinc oxide and oxybenzone
- Recognize the safety issues associated with UV, tanning, and sun exposure

Materials

Must use a UV Spectrophotometer, capable of reading in the 290-400 range.

Stock Solution: *1.00 g of the sunscreen with zinc oxide and 1.00g of the sunscreen with oxybenzone was mixed with warm isopropyl alcohol. The mixture was diluted to 100 mL and allowed to stand until any insoluble materials settled out. They are labeled as Sunscreen Stock Solution #1 and Sunscreen Stock Solution #2.*

Small cork ring

5 mL volumetric flask and stopper

Spectrophotometer with Cuvettes

Micropipette and Disposable Pipettes

Kimwipes

Graph Paper

Lab Safety

Always remember to follow the posted lab safety and waste disposal instructions. Please visit the American Chemical Society for Safety Guidelines.

<http://www.acs.org/content/acs/en/education/policies/safety.html>

Method and Instructions

Preparing Dilute Solution from the Stock Solution

1. Use small cork ring to protect your 5-mL volumetric flask.
2. Use 50 μ l of your Sunscreen Stock Solution #1.
3. Dilute with reagent grade isopropyl alcohol to 5 mL volume.
4. Stopper the flask and mix well.
5. Transfer some of your diluted sample to a disposable cuvette.
6. Repeat for Sunscreen Stock Solution #2.

Measuring Absorption via the Spectrophotometer

1. Plug in and turn on (left hand front dial, labeled ZERO in the illustration). Allow about 30 minutes for warm up.
2. With no cuvette in the chamber, a shutter cuts off all light from passing through the cuvette chamber. Under this condition, the machine may be adjusted to read infinite absorbance (zero% transmittance) by rotating the zero adjust knob. *Do not touch this knob again during the rest of the following procedure.*
3. Select the desired wavelength of light at which absorbance will be determined by rotating wavelength selection knob until the desired wavelength in nanometers appears in the window. *Start with 290 and repeat entire process at intervals of 10 from 290 to 400.*
4. Fill the B (blank) cuvette with the solvent used to dissolve specimen (isopropyl alcohol). Polish to clean, insert into the cuvette chamber. Close chamber cover.
5. Rotate blank adjust knob to adjust absorbance to read zero.




6. Remove blank cuvette, place in plastic test tube rack.

7. Pour the sample into the Sunscreen Stock Solution #1 into the cuvette, polish and insert into the chamber.

8. Note that the scale for absorbance is the lower scale on the dial, and should be read from R to L. Record absorption value.

9. Repeat procedure with the same sample but now at a 300 wavelength. Repeat entire procedure for each wavelength in intervals of 10 until 400.

10. Repeat all procedures for Sunscreen Stock Solution #2, as time permits.



10. Chart the absorption (y-axis) versus the wavelength (x-axis) for each Sunscreen Stock Solution using graph paper. Graph each sample on separate graphs.

11. Determine the where the highest absorption at which wavelength by examining your graph.

Laboratory Questions


What was the wavelength that showed the highest absorption for each sample and how did you know that?

What does the data on the two graphs say about efficiency of a zinc oxide versus an oxybenzone-based sunscreen?


Since sunburn is associated with skin cancer, how could you lower your risk of cancer caused by UV exposure from excessive sun?



How will this activity/unit impact your choices and behaviors in regard to your health?



Will you make a conscious decision to alter your purchases? Why or why not?



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