Sunscreen

Or: How I learnt to stop worrying and love UV radiation

- WORK IN GROUPS OF 4

Introduction:

The light emitted from the sun, a relatively nearby (~1.5 x10^8 km) G2 V yellow dwarf star, can be approximated as that of a black body with a surface temperature of ~5560 (the temperature of the photosphere).

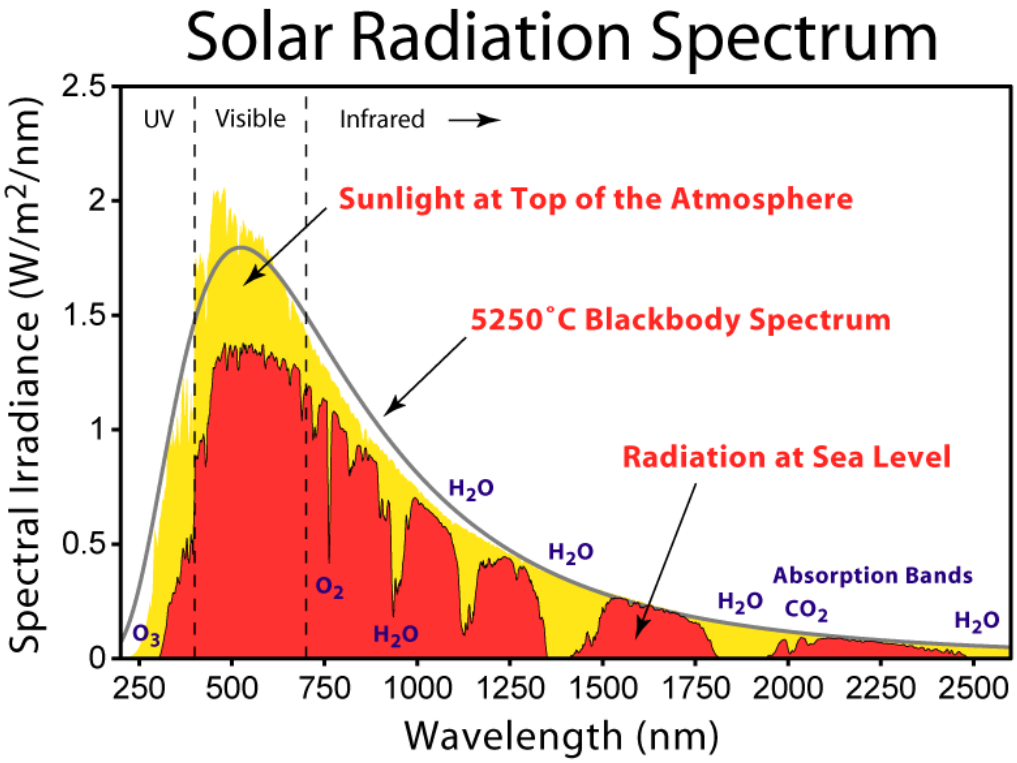

Figure 1: Solar Spectrum *physicsforums.com*

While this spectrum peaks in the visible, a significant proportion of the suns radiation is emitted at ultraviolet (UV) wavelengths. This ionising radiation has been known to cause skin cancer in humans, including the lethal malignant melanoma. In 2005 there were 10,684 new cases of melanoma diagnosed. In that same year, melanoma was responsible for 1272 deaths.

Scientists can be exposed to additional sources of UV radiation, including ultraviolet lamps and UV lasers (such as Excimer lasers or frequency doubled lasers). Several such lamps and UV lasers are used in the chemistry school.

Types of UV radiation:

Ultraviolet radiation is often broken up into 3 subtypes, based on its wavelength and the risk that is posed.

UVA: *400nm-315nm***:** The least harmful subtype of UV. UVA reportedly causes such adverse effects as loss of collagen, a decrease in the quantity of blood vessels, and an alteration of connective tissue of the dermis (1). While protection from UVA is desirable, it is not included in SPF ratings for sunscreens.

UVB: *315nm-280nm:* This radiation is responsible for tanning, sunburn and is the class of radiation most responsible for skin cancer.

UVC: *280nm-100nm:* While this form of radiation is highly dangerous, it is absorbed by the atmosphere and therefore poses a limited threat to the bulk of humanity. Most UVC is absorbed in the ozone layer, due to the photodissociation of ozone.

$$O_{3(g)} \xrightarrow{UV} O_{2(g)} + O_{(g)}$$

Therefore, in areas where the ozone layer has been depleted (such as at the earths poles) UVC can represent a serious hazard. In the late 20th century, as a direct result of the danger posed by UVC radiation, international legislation was introduced controlling the use of ozone depleting chemicals.

Sunscreens:

To reduce the risk of skin cancer and sunburn many humans use protective clothing, glasses and chemical sunscreens while in the sun.

Sunscreens work by forming a layer above the skin which absorbs dangerous UV radiation. They are rated by a sun protection factor (SPF),

$$\text{SPF} = \frac{\text{MED for skin with sunscreen(2 mg/cm2)}}{\text{MED for skin without sunscreen}}$$

where "minimal erythemal dose" (MED) is the length of time that one can stay in the sun before getting sunburned.

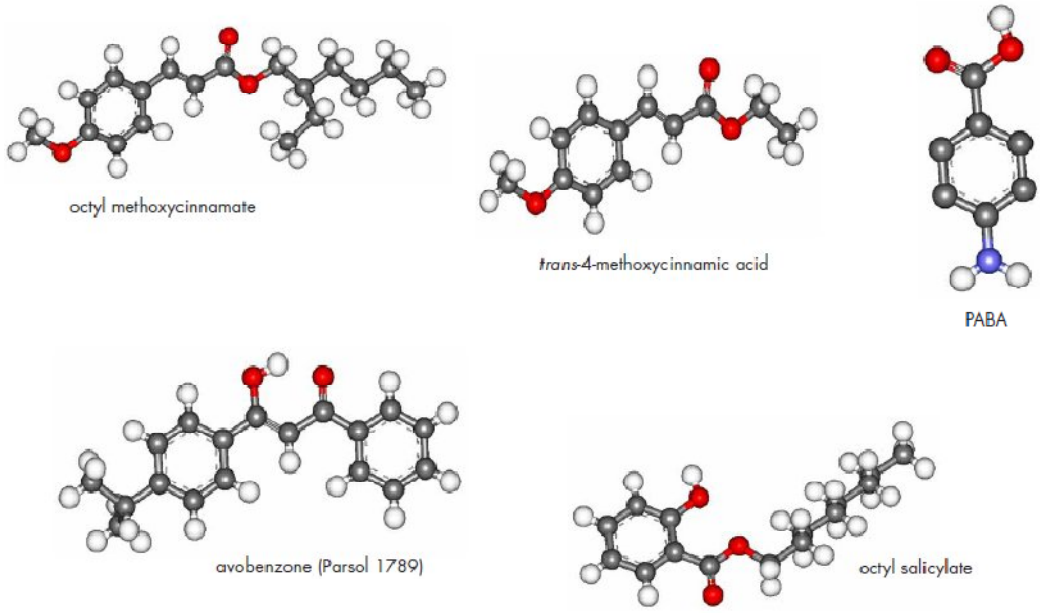

Figure 2: Molecular structure of some common sunscreens
http://www.jce.divched.org/JCEWWW/Features/MonthlyMolecules/2004/Oct/index.html

Experiment 1: UV Spectra of Sunscreens

- Wear gloves while using organic solvents
- Do not handle transparent windows of curvets
- Make up all solutions in lab before entering instrument room. Fill and empty curvets in main lab.
- DO NOT MAKE A MESS IN THE INSTRUMENT ROOM

You have a series of commercially available sunscreens.

1) Perform a baseline subtraction using a curvette of 2-propanol. (note: this takes several minutes so start this first and then do part 2 while running).

- Insert curvette
- Set wavelength range 190nm – 500nm
- Push F1

2) In small conical flasks dissolve ~ 1 drop of each sunscreen in ~ 100ml of 2-propanol (aka isopropanol / isopropal alcohol). Do this for each sunscreen. Note: The zinc cream doesn't dissolve properly, but enough enters solution to take a spectrum.
3) Take the UV - spectrum of each sunscreen. If absorbance is maxed out, dilute sample and try again. Record your observations. Pay particular attention to any areas where the sunscreen does and does not absorb.

Questions:

1) Which sunscreens provide better protection against UVA and UVB?
2) Does the tanning oil provide any protection from the sun?
3) In Antarctica which sunscreen would offer better protection and why?
4) The laser spectroscopy lab in the Madsen building has lasers with the following wavelengths: 355nm, 308nm, 266nm, 248nm, 193nm. For diffuse reflected light from these lasers, would any of the sunscreens provide protection for all these wavelengths?

Experiment 2: Concentration Dependence

The absorbtion of radiation can be described by the Beer-Lambert law

$$-\log\left(\frac{I(\lambda)}{I_0(\lambda)}\right) = \varepsilon(\lambda)cl$$

Where the quantity -log (I /I_0) is termed the absorbance, c is concentration and l is path length (2). What would you expect to happen to the absorbance of sunscreen if you halve the concentration of your solution?

Test this for one of your samples.

What are the practical connotations for commercial sunscreens?

Experiment 3: The Case of the Mad Dog Murderer

You are now part of the forensic team on the trail of the "Mad Dog Murderer," a notorious serial killer who kills his victims by beating them to death with cute innocent puppies. He must clearly be stopped. The investigation has narrowed the suspects down to two, Billy and Bob.

A white singlet top, believed to belong to the killer, was found at the last murder site. A quick examination revealed that the singlet is covered in coconut oil. A search of the apartment showed that Billy had *Reef dark sun tan oil* in his sports bag, and Bob had *LeTan coconut sunscreen oil (SPF4)* in his kitchen. A fabric sample from the top is provided.

Using your forensic kit of 2-propanol, a test tube, a pair of scissors, a stirring rod, a dropper, a paper clip, a rubber band and a UV-Vis spectrometer, identify the mad dog murderer and make the world safe for puppies and people everywhere.

Experiment 4: Eye protection

The eyes of humans are also susceptible to ultraviolet radiation. To determine what protection is provided record the absorption spectra of safety glasses, sunglasses and regular glass and silica.

- Run a new baseline correction with nothing in the beam path (no curvet)
- Place material in the beam path
- Run scan (pay attention to the wavelengths that the material is opaque)
- To run the silica spectrum, use an empty curvet
- To run the glass, use a conical flask with the neck in the beam path

Questions:

1) What glasses provide protection for UVA, UVB and UVC
2) Which glasses provide protection against diffuse reflections from the lasers mentioned in part A (this is important as even diffuse reflections from class IV lasers can cause eye damage)? Would any of these glasses provide protection against the 532nm (Green) output of a frequency doubled Nd:YAG laser?

Experiment 5: The Science of Practical Jokes and Eeeeeevil!!!

Dr Purplepants, an evil genius, is at the beach with Captain Hopscotch, a hero. It is revealed that Captain Hopscotch will later that night be competing in the annual *hero's night club boogie groove fest*, to take place under black lights. As such, Captain Hopscotch is wearing is finest white shirt. Dr Purplepants strikes. He sneaks up behind the hero and sneakishly writes the symbol of evil awesomeness on the back of Captain Hopscotch's shirt **in sunscreen**. Will Captain Hopscotch be branded an

evil lover by his peers, or has Dr Purplepants wasted perfectly good sunscreen?!!! Test your theory using the UV lamps provided.

References:

1): Siegel, M. *Safe in the Sun*. Walker and Company: New York, 1990
2) J R Abney, B A Scaletter *JChemEd* **75** 757-760 (1998)