Effectiveness of Nivea Sunscreen under Ultraviolet Light

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Abstract

The relationship between a sunscreen's SPF and its absorbance for UV light of wavelength 240 to 320 was investigated. The investigation was conducted by diluting sunscreens with SPFs of 20, 30 and 50 and placing the solution in a spectrophotometer where the absorbance was measured under UVA, UVB and UVC light. It was shown that the sunscreen was effective over the whole range of wavelengths, with increased effectiveness at wavelengths 240 and 300. The results also show that as the SPF increased, the absorbance increased proportionally.

Introduction

Sunscreen has commonly been used to prevent ultraviolet radiation from damaging our skin. A variety of ingredients which absorb ultraviolet light, such as titanium dioxide or zinc oxide, are used. On every bottle of sunscreen, there is an indication of its Sun Protection Factor (SPF) which is a measure of the sunscreen's protection, or absorption, of UVB. A sunscreen with an SPF of 20 would allow a person to be exposed to sun without being burned 20 times longer than the time that it would take to burn the same person without using sunscreen.

A sunscreen's absorbance is the proportion of the light that is absorbed by the sunscreen. It can be represented by the equation:

$$A_\lambda = \log_{10}(I_0/I) \qquad \text{(Eq 1)}$$

Where A is the absorbance, I_o is the intensity of the light before it enters a sample and I is the intensity of the light that has passed through the sample.

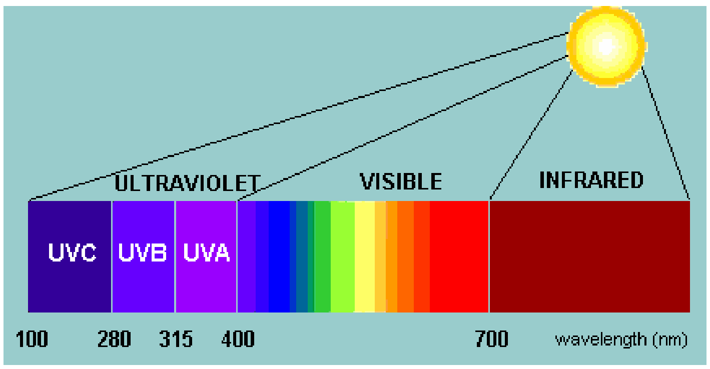

Figure 1: Wavelengths of various types of light. Note that UV light is divided into three ranges; UVA, the least harmful, to UVC, the most harmful. (ARPANSA)

The absorbance is proportional to the thickness of the sample tested and the concentration of the absorbing species in that sample. As SPF is a measure of protection from UVB, it is based on ultraviolet light that has wavelengths from 280 to 315 nanometers. [Figure 1] The characteristics of the absorbance of sunscreen at wavelengths 220 – 320 was investigated for SPF 20, 30 and 50 sunscreen. The relationship between the concentration of sunscreen and absorbance was also studied for SPF 20 only. Nivea brand sunscreen was used which contained active ingredients titanium dioxide and zinc oxide.

Methods

A Lab Med Digital spectrophotometer (Spectro UV-VIS RS) was set to use ultraviolet light. A diluted solution of sunscreen with a concentration of 0.05 g/L of water was prepared. A quartz cuvette was filled with distilled water and placed into one of the slots in the spectrophotometer. Another cuvette was filled with the diluted sunscreen solution and then placed into another slot inside the spectrophotometer.

The wavelength on the spectrophotometer was set to 220 nanometers and the absorbance of the cuvette containing sunscreen solution was then measured and recorded three times. Each time the absorbance was zeroed by using the cuvette with distilled water.

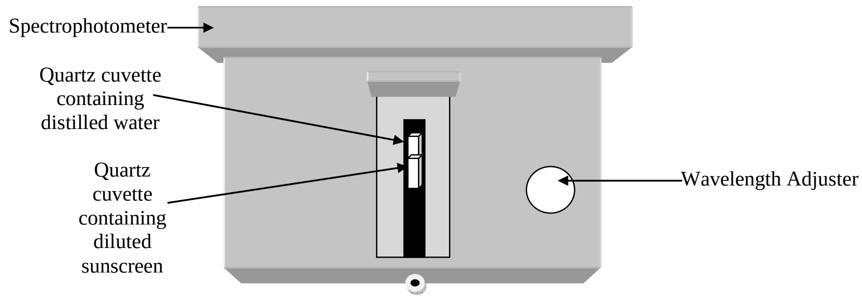

Figure 2: Set up of the investigation which includes two quartz cuvettes placed inside a spectrophotometer to be examined under a particular wavelength.

This process was repeated for wavelengths 240, 260, 280, 300 and 320 nanometers and for sunscreens of SPF 30 and 50. Two additional trials were then performed using SPF 50 sunscreen with concentrations of 0.01 g/L of distilled water and 0.04 g/L of distilled water.

Results and Discussion

Absorbance and SPF

The absorbance of each SPF under the various wavelengths was tested using concentrations of 0.05 g/L. The graph of the relationship between SPF and Absorbance under a wavelength of 260 nm is shown in figure 3. A linear relationship, within uncertainties, is demonstrated. It is concluded that doubling the SPF of your sunscreen will double the absorbance of the UV light before it reaches your skin. The equation derived for the absorbance of 260 nm light going through a standard cuvette filled with a solution of 0.05 g/L solution of Nivea sunscreen can be expressed as:

$$A = (0.0071 \pm 0.0002)S + (0.027 \pm 0.008) \quad \text{(Eq 2)},$$

where A is equal to the absorbance and S is the SPF of the sunscreen.

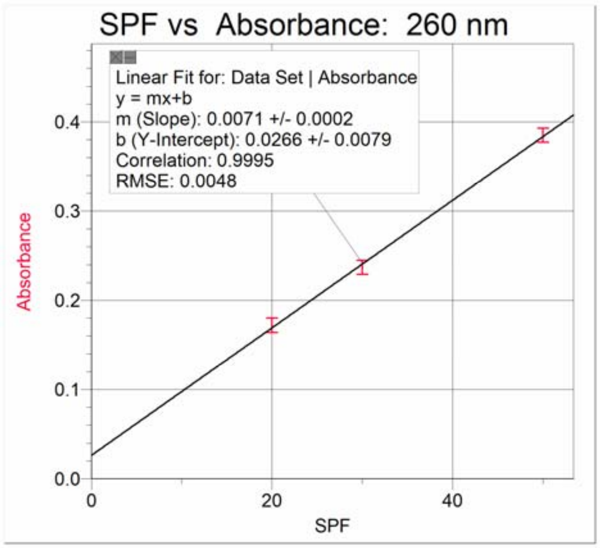

Figure 3: SPF of sunscreen as a function of absorbance for a solution of 0.05 g/L of Nivea sunscreen using UV light of 260 nm. A linear relationship is shown.

The relationship between SPF and absorbance for all wavelengths in the range 220 nm to 320 nm was graphed and the results averaged together. The resulting average relationship for all wavelengths was found to be:

$$A = (0.009 \pm 0.002) * S + (0.00 \pm 0.05) \quad \text{(Eq 3)},$$

It is interesting to note that the average absorbance for SPF 0 is 0.00 ± 0.05, as expected, indicating that a lotion of SPF 0 would not block any UV light.

Absorbance and Concentration

Solutions of SPF 50 sunscreen were made with concentrations of 0.01, 0.04 and 0.05 g/L. These solutions were then tested with UV light of wavelength 280 nanometers. It was found that there was a linear relationship between the concentration and the absorbance of the solution. As the concentration of the solution of sunscreen increases, the absorbance increases proportionally. It can be concluded that the thickness of the layer of sunscreen on the skin is proportional to the absorbance of the UV light in the sunscreen before it reaches the skin. This can be shown by the equation:

$$A = (7.0 \pm 0.2)\, C + 0.04 \pm 0.01 \quad \text{(Eq 4)},$$

where A is equal to the absorbance and C is the concentration of the solution of sunscreen.

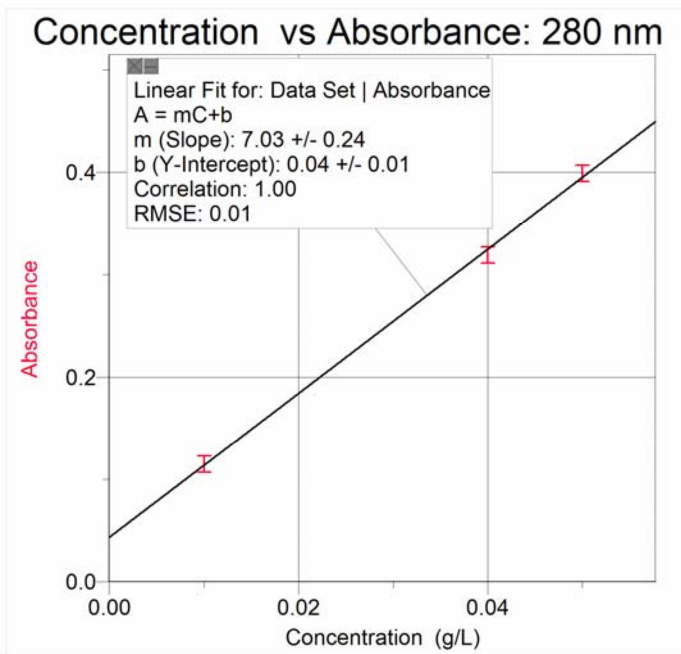

Figure 4: Concentration of SPF 50 sunscreen as a function of Absorbance for UV light of 280 nm. A linear relationship is shown.

It should be noted that the graph does not originate at the origin, as expected. Further research must be done to determine the relationship between absorbance and concentration at very low concentrations.

Absorbance and Wavelength

The absorbance of solutions of 0.05 g/L of sunscreen with SPF 20, 30 and 50 were measured. The results concluded that there are certain wavelengths that each of the SPF's work most effectively at. From figure 5, it is clear that there is a pattern in the relationship between the wavelength and the average absorbance. All three SPF's showed two peaks in absorbance. The wavelengths at which the sunscreens work most effectively are 240 nm in the UVA range and 300 nm in the UVC range. It was noted that the greater the SPF of the sunscreen, the greater the relative increase in effectiveness for these wavelengths. It was also noted that there is a general trend of decreasing absorbance with increasing wavelength. Interestingly, the absorbance is shown to be relatively low for UVB for all three sunscreens.

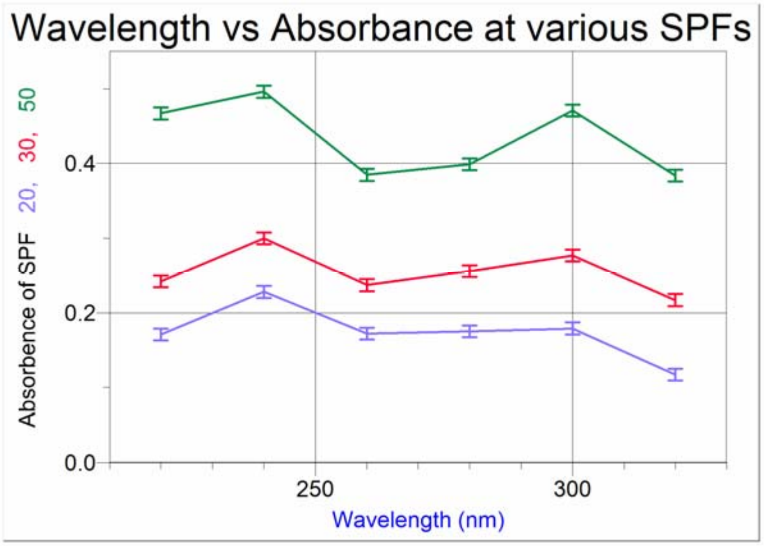

Figure 5: Absorbance of various SPF sunscreens as a function of wavelength for UV light from 220 nm to 320 nm. The sunscreens show increased effectiveness at wavelengths of 240 nm and 300 nm.

Conclusion

The relationship between the SPF of sunscreen and its absorbance was shown to be proportional, as expected. The relationship between the absorbance of sunscreen and the concentration of sunscreen of SPF 50 was linear. The results unexpectedly predict that a concentration of 0.00 g/L would not have an absorbance of 0.00. The relationship between absorbance and concentration for very low concentrations must be studied further. The absorbance of all the sunscreens was found to be fairly constant across the range from 220 nm to 340 nm, with small peaks in absorbance at 240 nm and 300 nm and a general trend of decreasing absorbance with increasing wavelength.

Evaluation

There were several weaknesses in this investigation. One weakness was that, due to time constraints, the spectrophotometer may not have been completely warmed up before the measurements were performed. The spectrophotometer should have been left on for approximately 30 minutes before being used. Another weakness was that there were only two quartz cuvettes. In order to perform each trial, the cuvettes had to be cleaned, however there may have been traces of the remaining solution. This can be improved by carefully cleaning the cuvettes using cotton buds. Another weakness in this investigation is that although the sunscreen used was from the same brand, the active ingredients varied between the different SPFs. A brand that sells sunscreen, with the same active ingredient for different SPFs should be used in future. It is suggested that the research is to be further continued using other brands of sunscreen, to see if the relationships found here are true for all sunscreens.

References

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