The Level of UV Transmittance in Various UV Labeled, Disposable, Soft Contact Lenses

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Class of 2001

Abstract

With the recent evidence of acute and chronic ultraviolet radiation (UVR) effects on the eye, soft contact lens manufacturers have incorporated UV blockers into the lenses. This study will determine the percent transmittance of UVR through seven disposable, soft spherical contact lenses designed with UV protection (UV-SCL). The Beckman DU 640 B spectrophotometer was used to measure the transmittance curves of the contact lenses within the radiation wavelengths of 270 to 500 nm. First, the percent of transmittance will be compared to lens power using -3.00 D, +3.00 D, and +6.00 D in CooperVision, Ocular Science, Vistakon and Wesley-Jessen UV labeled lenses. Second, evaluation of UVR transmission curves between the seven UV-SCLs will compare manufacturer claims and actual UV protective ability. Our results indicate that lens power and center thickness do not significantly effect UVR transmission through UV labeled SCLs. In conclusion, current UV-SCLs provide significant UVR protection in comparison to SCLs without this protection; yet do not achieve the complete protection to 400 nm that UV coated spectacle lenses achieve.

Introduction

Acute and chronic exposure to UVR is correlated to damage to the eyes and vision. UVR has been further subdivided to UVC (100-280 nm), UVB (280-315 nm), and UVA (315-400 nm) (Harris et al. 1993). UVC is absorbed by the atmosphere and does not reach the earth's surface. The recent depletion of 10% of stratospheric ozone (Meyer-Rochow 2000) has led to an increase in radiation of wavelengths 288 – 340 nm (Quesnel and Simonet 1995). In some portions of the world, such as New Zealand, even winter exposure to sunlight increases UVR risk (Meyer-Rochow 2000). Daily exposure to UVR is dependent on time of day, time of year, duration of exposure, geographic location, environmental conditions (snow, clouds, bodies of water), and the use of hats or sunglasses (Taylor 1995). Several conditions that require UVR protection include pseudophakia, aphakia, aniridia, albinism, working or relaxing outdoors, psoralen sensitized patients and other patients using photosensitizing medications (Abadi et al. 1989).

The various structures of the eye are affected by different UVR wavelengths. UVA and UVB have been associated with pinguecula and pterygia of the conjunctiva particularly in individuals residing in tropical climates. Arabs in the Red Sea region were found to have a high risk for developing pinguecula, however no direct epidemiological study has found pinguecula directly correlated with UVR. Pterygia on the other hand have a significant correlation to UVR exposure. A greater incidence of pterygia occurred in Australian aborigine, Eskimo, fishermen in Chesapeake Bay, and Japanese welders (Bergmanson and Soderberg 1995).

The cornea demonstrates a peak sensitivity to 270 nm resulting in damage to the epithelium, stromal keratocytes, and endothelium (Quesnel and Simonet 1995). Damage occurs acutely and cumulatively resulting in UV keratitis, photoophthalmia, snowblindness, and droplet keratopathy (Bergmanson et al. 1988). Morphology studies of rabbit corneal tissue after UV exposure revealed normal corneal morphology in rabbits fitted with a UV-blocking contact lens, and degenerative corneal morphology in rabbits fitted with a non-UV blocking contact lens (Bergmanson et al.1987).

The crystalline lens has a peak sensitivity to 300-320 nm wavelengths. Lenticular epithelial exposure leads to inactivation of critical enzymes of transport and metabolic processes resulting in altered fiber elongation (Hightower 1994). Intense, acute UVR leads to anterior cortical and anterior subcapsular cataracts. Doubling the time of chronic exposure to UVB, lead to cortical cataracts as found in the Chesapeake Bay waterman study (Taylor 1995). Repetitive doses of UVB prevent lens repair from occurring. Studies involving antioxidants found UVB induced lenticular changes were prevented, suggesting oxidative damage (Meyer-Rochow 2000). Other studies have used statistical means to determine exposure time versus damage as expressed in the following chart (Pitts and Kleinstein 1993 and Michael 1997).

Table 1: Calculations of safe ocular exposure times on the earth's surface at sea level under different concentrations of "effective" ozone (1 mm ozone = 100 Dobson units).

	Total terrestrial irradiance (W/m^2) UVB	UVA	Safe ocular exposure to avoid cataracts (minutes)
Without ozone	12.4	55.2	6
"2 mm" ozone	2.6	54.6	30
"4 mm" ozone	1.7	54.2	48

UVR possesses high energy per photon and only one photon is needed to damage the retina (Pitts 1990). Wavelengths of 350-380 nm effect photoreceptors while wavelengths of 440-500 nm affect retinal pigment epithelium (Meyer-Rochow 2000). The decrease in ozone has lead to an increase in solar retinitis (Bergmanson and Soderberg 1995). Increased UVA may be associated with increased incidence of cystoid macular edema (Harris et al. 1999). UVR may also be associated with age-related macular degeneration (Hickson-Curran et al. 1997).

UVR protection has been offered in spectacles and more recently in soft contacts lenses (SCL). Wesley-Jessen, Inc., holds the patent for UVR absorbing SCLs. One stipulation of the patent was to block less than 30% of visible light in the 340nm to 450nm range. According to the patent, the UVR absorbing dye may be added to the contacts in two ways: before the final curve determining the lens prescription is applied or after the entire lens is fabricated. Finally, any extraneous absorbing dye must be extracted from the lens due to its toxicity to human eyes. The duration and temperature of this extraction results in higher transmission percentages of UVA in the 360 – 400 nm wavelengths (Wesley-Jessen 1981).

The UV absorbing components of SCLs are integrated into the monomer thus eliminating the potential for leaching during wear. The UVR is neutralized by converting the energy to heat, which is then lost from the front surface of the lens (Quesnel and Simonet 1995). There are two types of UV blockers in SCLs. Used earlier, benzophenone based blockers were attached covalently to the lens polymer matrix and blocked up to 360 nm. Next benzotriazole based blockers were covalently linked to the lens polymer and blocked up to 380 nm. Then it was found that halogenation of benzotriazole provided blockage close to 400 nm (Anstey et al. 1999).

Spectacle lenses can be treated with UV tints to block up to 400 nm. Studies have found that even one year after use, these spectacle lenses transmitted only 0.15% of UVA. This falls within the most stringent UVA requirement of ANSI Z80.3-1996 which allows 1.5% transmittance of UVA (Lee et al. 1997). This is the current standard for nonprescription sunglasses. Despite the low transmittance through the lenses, approximately 4% of UVB gets around the lenses and frame to the eyes (Taylor 1995). Soft contact lenses have been evaluated by ANSI standard Z80.20 for Class 2 UV blockers allowing a maximum of 30% transmittance of UVA wavelengths and 5% of UVB wavelengths (Harris et al. 2000).

This study will evaluate the percent transmittance of UVA,UVB and UVC in spherical, soft, disposable contact lenses marked UV-blocking and non-UV-blocking as a control. A comparison will be made between the various UV-blocking brands and between lens power of the same brand.

Materials and Methods

Contact Lenses

The parameters of the UV-absorbing lenses used in this study are listed in Table 2. These lenses were selected from Tyler's Quarterly based on the UV-absorbing description. The control lens was Ciba Focus monthly since it was not listed as UV-absorbing in Tyler's Quarterly. The sample studied consisted of one unused soft lens of each type. Different lens powers were used in the study to determine whether thickness or power affected the transmittance factor of the lens. The lenses chosen were ordered in three powers: +6.00 D, +3.00 D, -3.00 D. Some lenses measured at +/- 0.25 D based on manufacturer availability. A -6.00 D lens was also substituted when a high plus power lens was unavailable. The base curves, diameters, center thickness, and materials varied between manufacturers.

Instrument

The Beckman DU 640B Spectrophotometer was used to test each soft lens. This instrument plots the percent transmittance of the sample lens as the wavelength is scanned. The wavelength is measured in nanometers (nm) from 270 to 500 nm. The wavelength repeatability at full range is +/- 0.2%.

Experimental Procedures

Before each group of SCLs was tested, a blank tori-check apparatus was run to calibrate the system. Each SCL was removed from its vial with soft tweezers and the surface was blotted dry with a Kim Wipe. The soft lens was then placed onto a tori-check apparatus, convex side facing the scanning beam, and attached at a pre-measured position inside the spectrophotometer. The trial lens was read within a three minute time period to prevent excessive dehydration and inaccurate readings. All measurements were carried out at room temperature. The spectral transmittance was measured at a 35 second interval over the range of 270 – 500 nm. The instruments scan speed was 1200 nm/min. After testing, the results were printed out for further comparison and interpretation.

Table 2: Soft contact lens parameters used in the study.

Brand	Manufacturer	Power	Base Curve	Diameter	CT	Material & % H2O
Ciba Focus Monthly (non-UV)	Ciba	+6.00 DS	8.6	14.0	*	Vifilcon A
		+3.00 DS	8.6	14.0	0.15	55%
		-3.00 DS	8.6	14.0	0.10	
Precision UV	Wesley-Jessen	+6.00 DS	8.7	14.4	*	Vasurfilcon A
		+3.00 DS	8.7	14.4	0.26	74%
		-3.00 DS	8.7	14.4	0.14	
Permaflex UV Natural	CooperVision	+3.25 DS	8.7	14.4	0.18	Surfilcon A
		-3.25 DS	8.7	14.4	0.10	74%
		-6.00 DS	8.7	14.4	*	
Acuvue 2 UV	Vistakon	+6.00 DS	8.7	14.0	*	Etafilcon A
		+3.00 DS	8.3	14.0	0.17	58%
		-3.00 DS	8.7	14.0	0.084	
Acuvue UV	Vistakon	+6.00 DS	9.1	14.4	*	Etafilcon A
		+3.00 DS	9.1	14.4	0.17	58%
		-3.00 DS	8.8	14.0	0.07	
Acuvue 1-day UV	Vistakon	+6.00 DS	8.5	14.2	*	Etafilcon A
		+3.00 DS	9.0	14.2	0.20	58%
		-3.00 DS	9.0	14.2	0.07	
Survue UV	Vistakon	+6.00 DS	9.1	14.4	*	Etafilcon A
		+3.00 DS	9.1	14.4	*	58%
		-3.00 DS	9.1	14.0	0.105	
Diagnostic Lens 60 UV	Ocular Science	-3.00 DS	3.75 sag	14.4	0.07	Ocufilcon
		-6.00 DS	3.75 sag	14.1	*	60%

*Specific center thickness not specified in Tyler's Quarterly.

Results

The spectrophotometer results for each lens are shown in Figures 1 to 23. Comparison of these transmission curves between the non-UV absorbing lens and the UV absorbing lenses reveals a steeper drop in the UVA range for the UV absorbing lenses. The non-UV absorbing lenses demonstrated a shallower and more gradual decrease in transmittance for UVA and UVB ranges.

Each transmittance curve was broken down into three sections: UVA (315-400 nm), UVB (280-315 nm), and UVC (100-280 nm). Table 3 lists the highest and lowest transmittance values in each of these UVR sections for all SCLs in this study. Table 4 lists the SCLs and whether or not each lens passed ANSI Z80.20 based on Figures 1 to 23.

Our research data found a strong correlation between the four Vistakon lenses used. The Acuvue, Acuvue 2, Acuvue 1-day, and Surevue lenses were all made out of Etafilcon A and had a center thickness range between 0.20 - 0.07 mm. The transmittance curves revealed that the thicker lenses (plus power) had greater UV transmittance than the thinner lenses (minus power). The only exception was the Acuvue 1-day +3.00 D lens which transmitted a large percent of UVR across the entire spectrum.

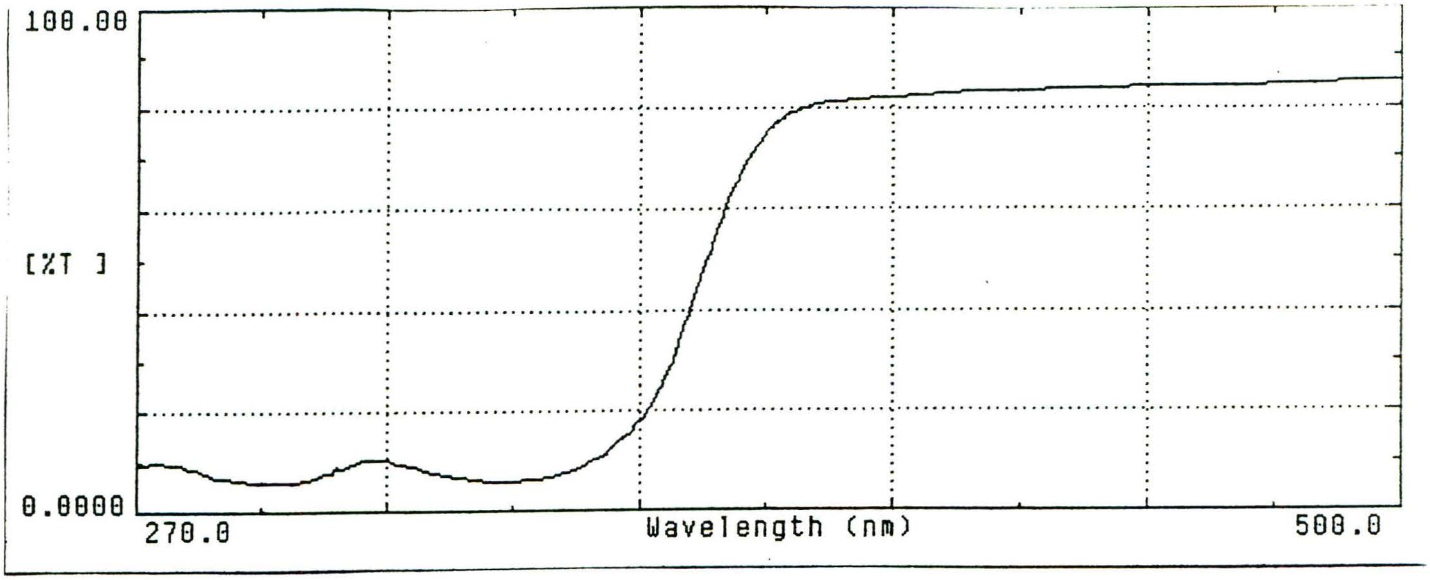
CooperVision's Permaflex UV Natural lenses demonstrated an increase in percent transmittance with thinner lenses (minus lenses). However, the –6.00 D lens had a high percent transmittance across the entire UVR spectrum.

Wesley-Jessen's Precision UV lens showed similar transmission characteristics between the +6.00 D and –3.00 D lenses. The +3.00 D had the greatest UVA transmission of all three lenses.

The Diagnostic Lens 60 resulted in slightly higher transmittance of UVA in the –6.00 D lens compared to the –3.00 D lens. No plus power lens was available for comparison.

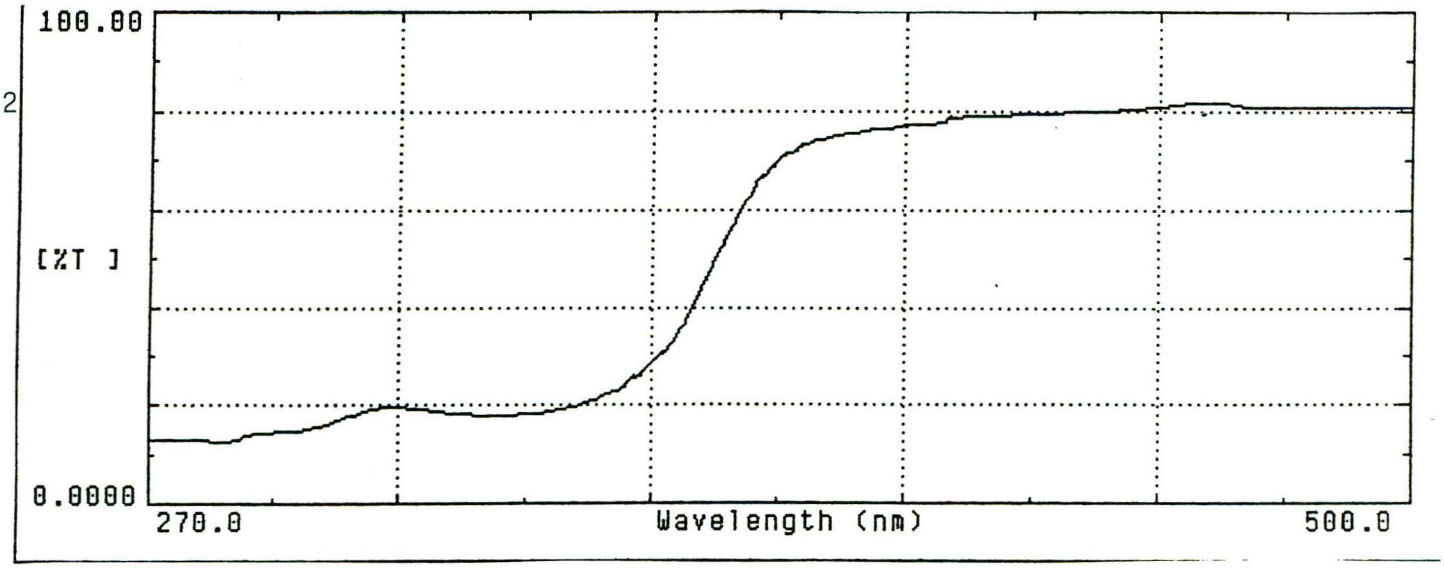
The control lens, Ciba Focus Monthly showed similar transmission characteristics between the three lens powers.

Figure 1



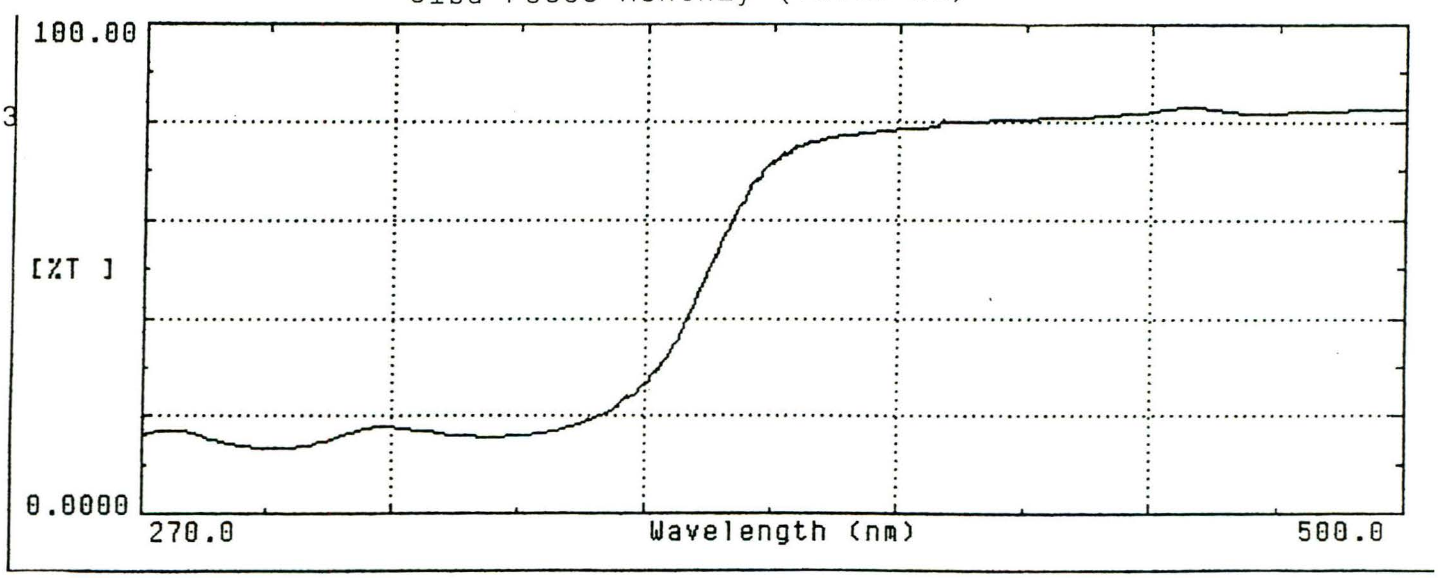
Ciba Focus Monthly (+6.00 DS)

Figure 2



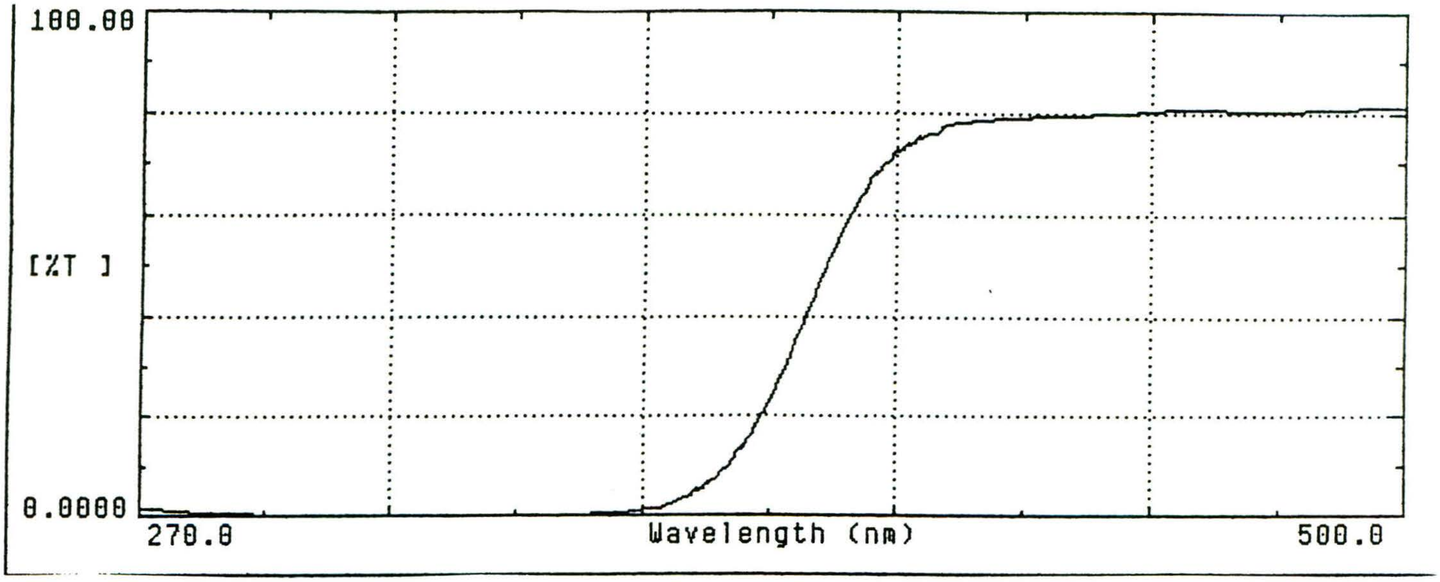
Ciba Focus Monthly (+3.00 DS)

Figure 3



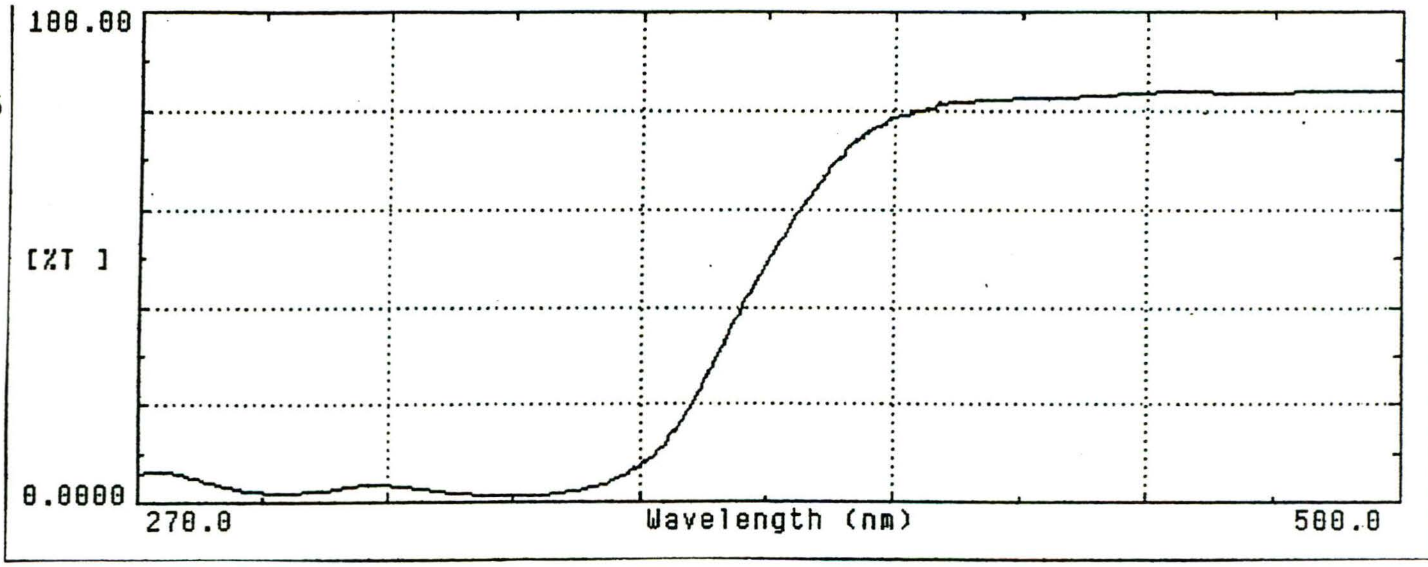
Ciba Focus Monthly (-3.00 DS)

Figure 4



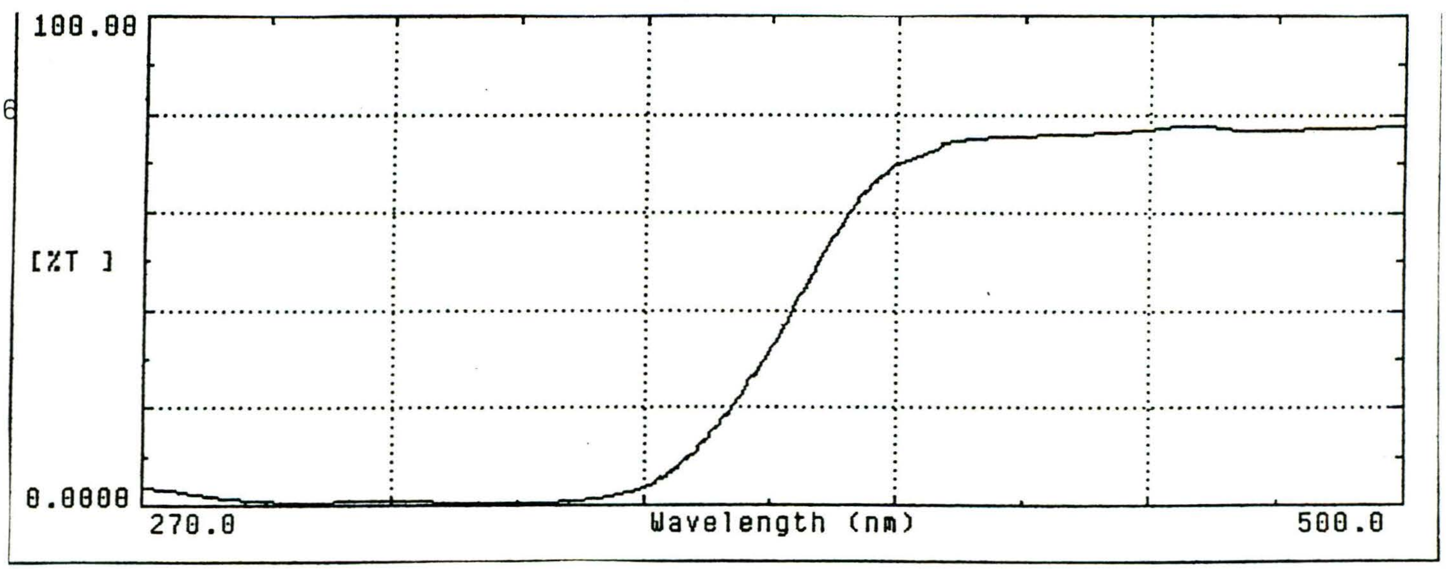
Precision UV (+6.00 DS)

Figure 5



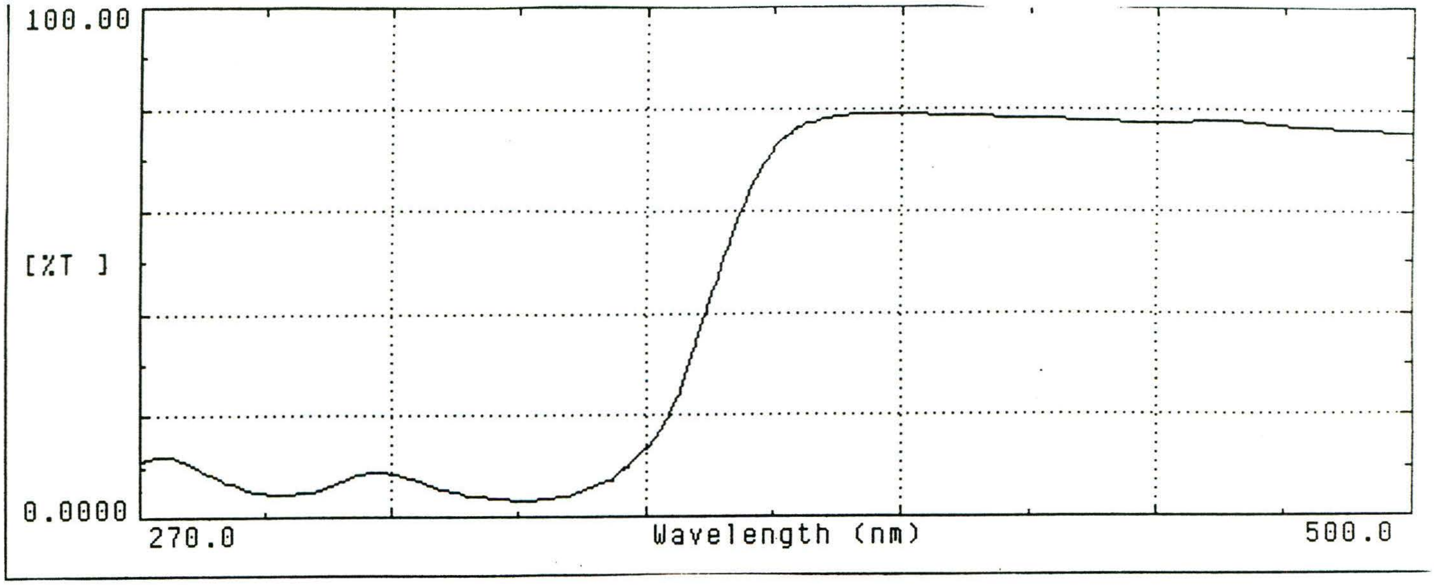
Precision UV (+3.00 DS)

Figure 6



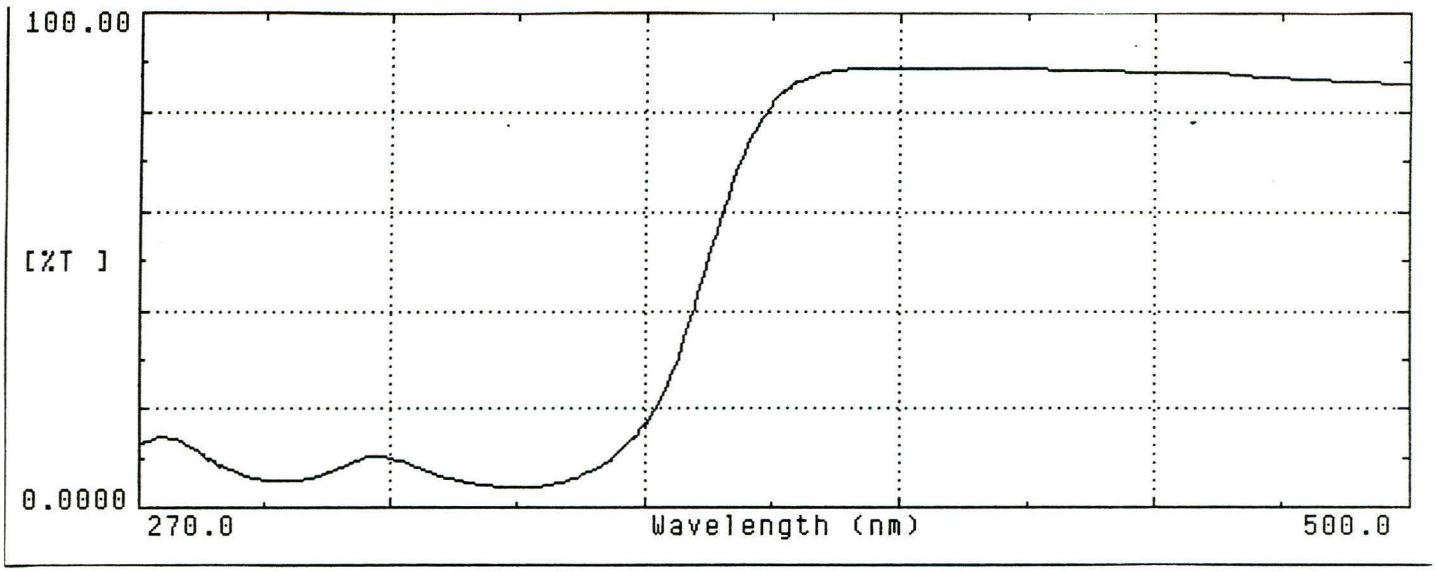
Precision UV (-3.00 DS)

Figure 7



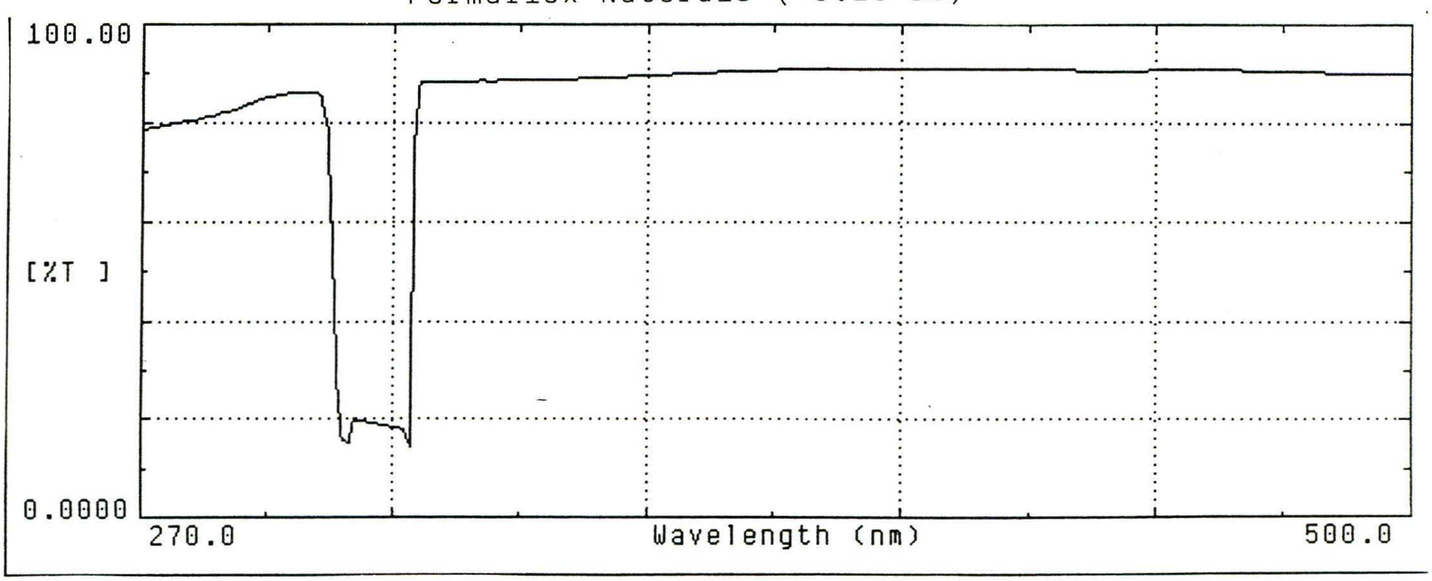
Permaflex Naturals (+3.25 DS)

Figure 8



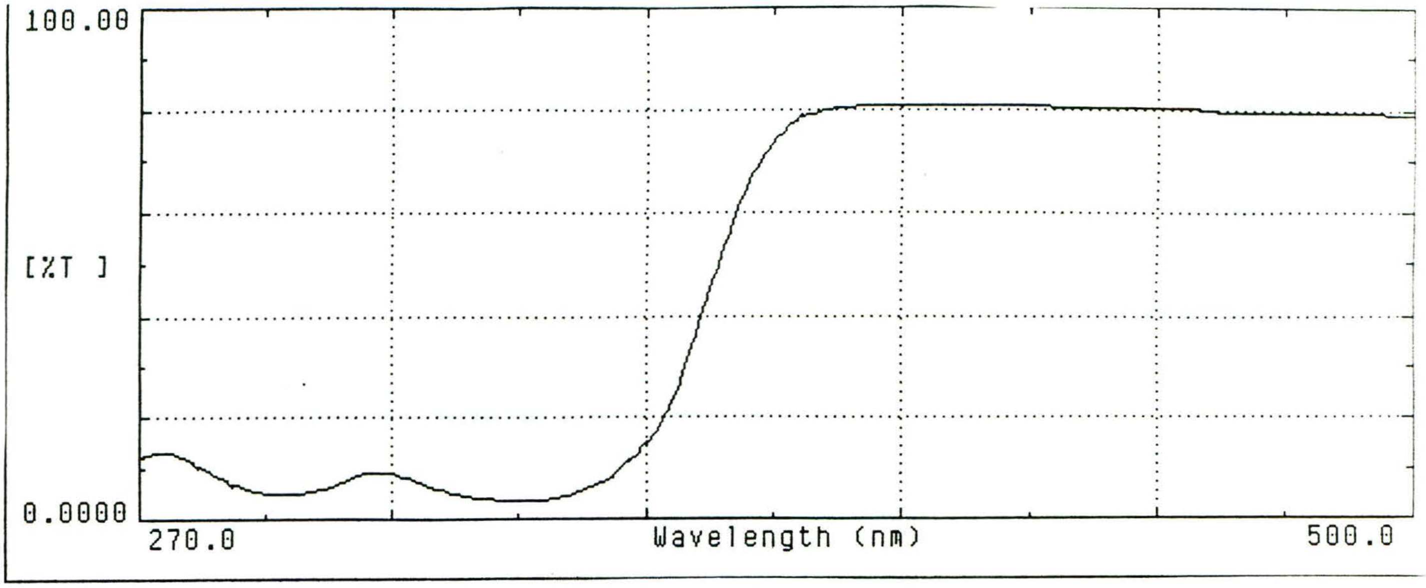
Permaflex Naturals (-3.25 DS)

Figure 9



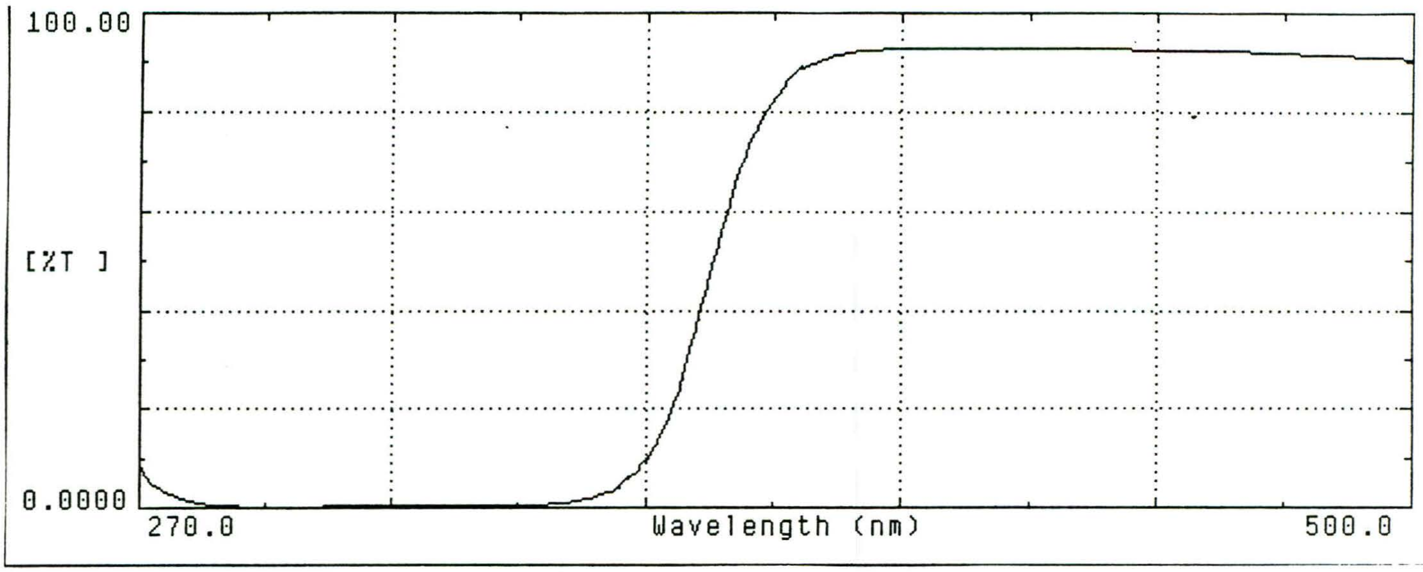
Permaflex Naturals (-6.00 DS)

igure 10



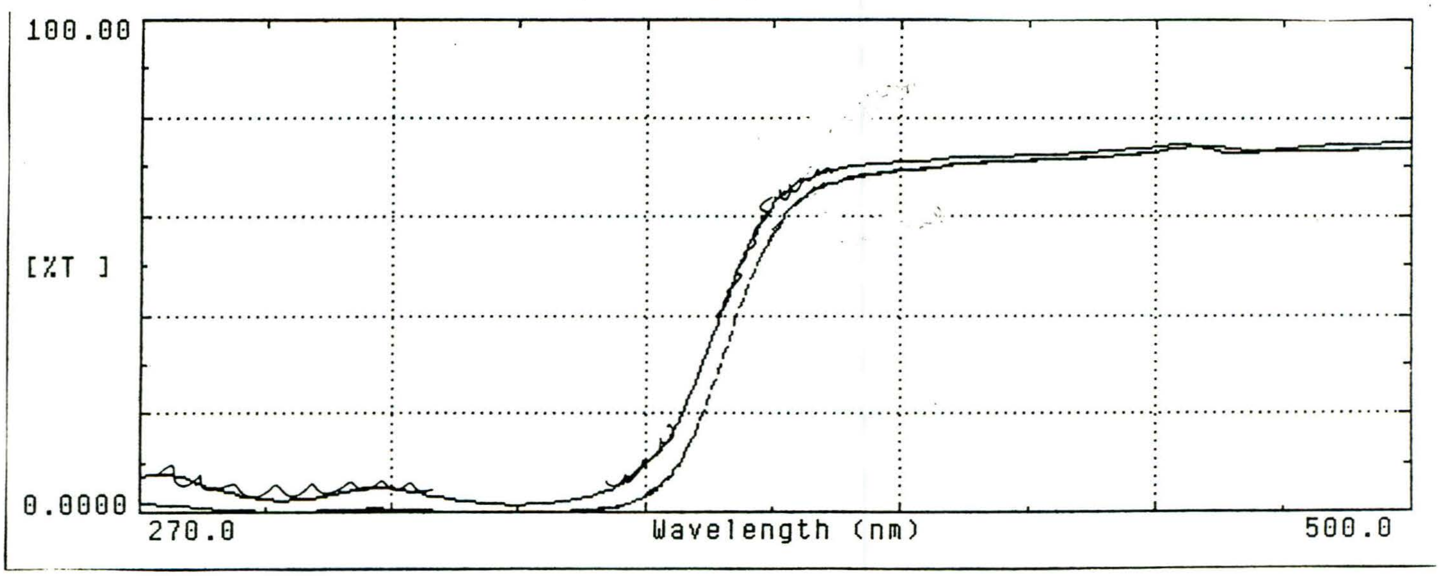
Acuvue 2 (+6.00 DS)

igure 11



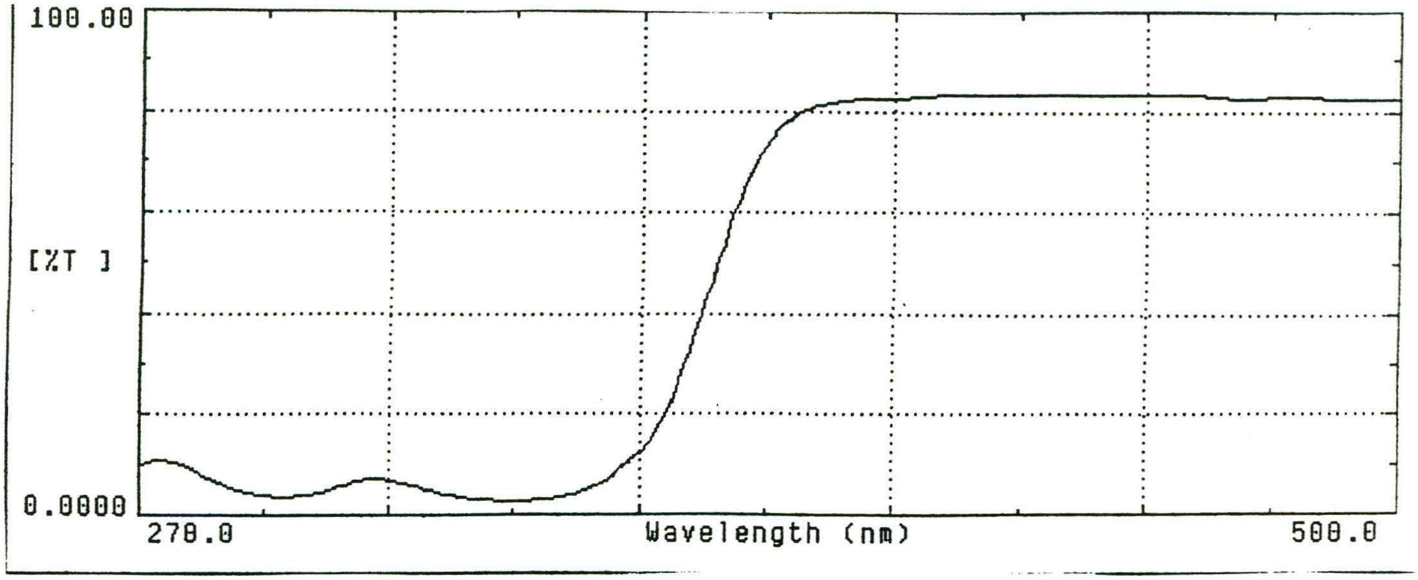
Acuvue 2 (+3.00 DS)

igure 12



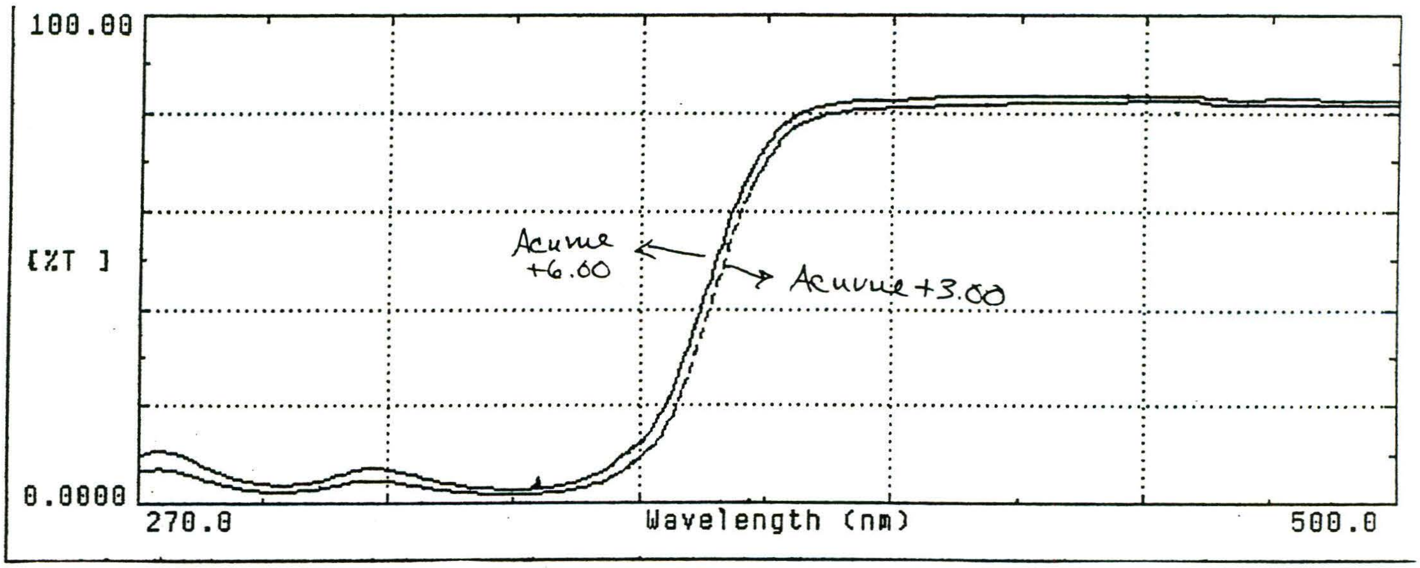
Acuvue 2 (-3.00 DS)

Figure 13



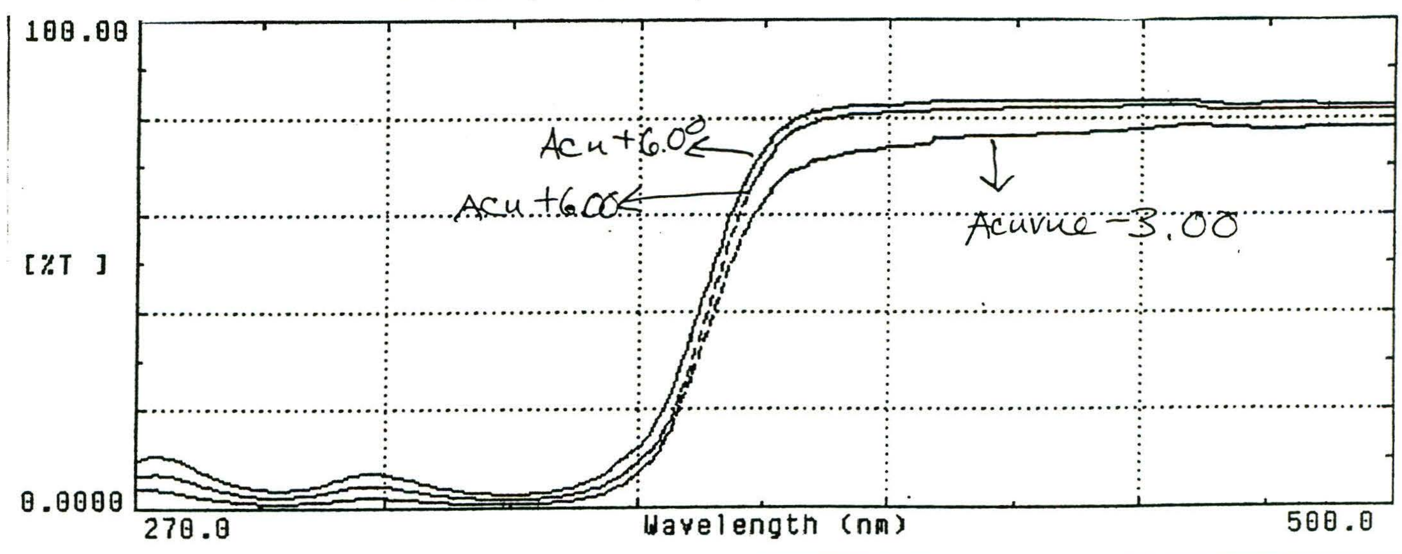
Acuvue (+6.00 DS)

Figure 14



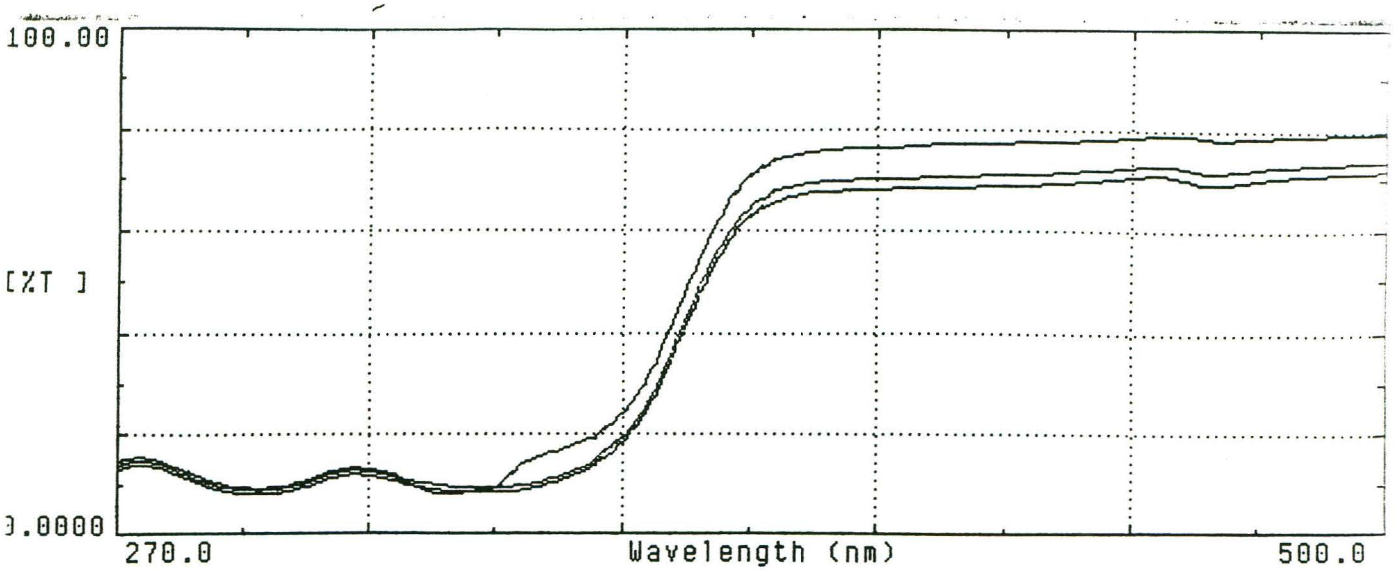
Acuvue (+3.00 DS)

Figure 15



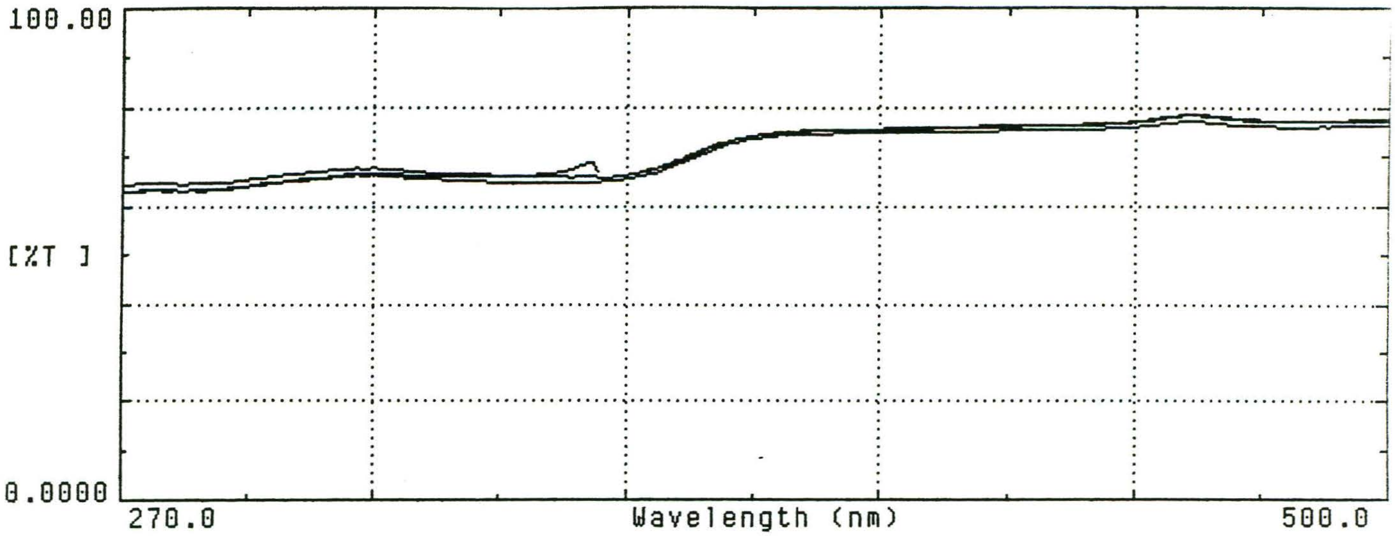
Acuvue (-3.00 DS)

Figure 16



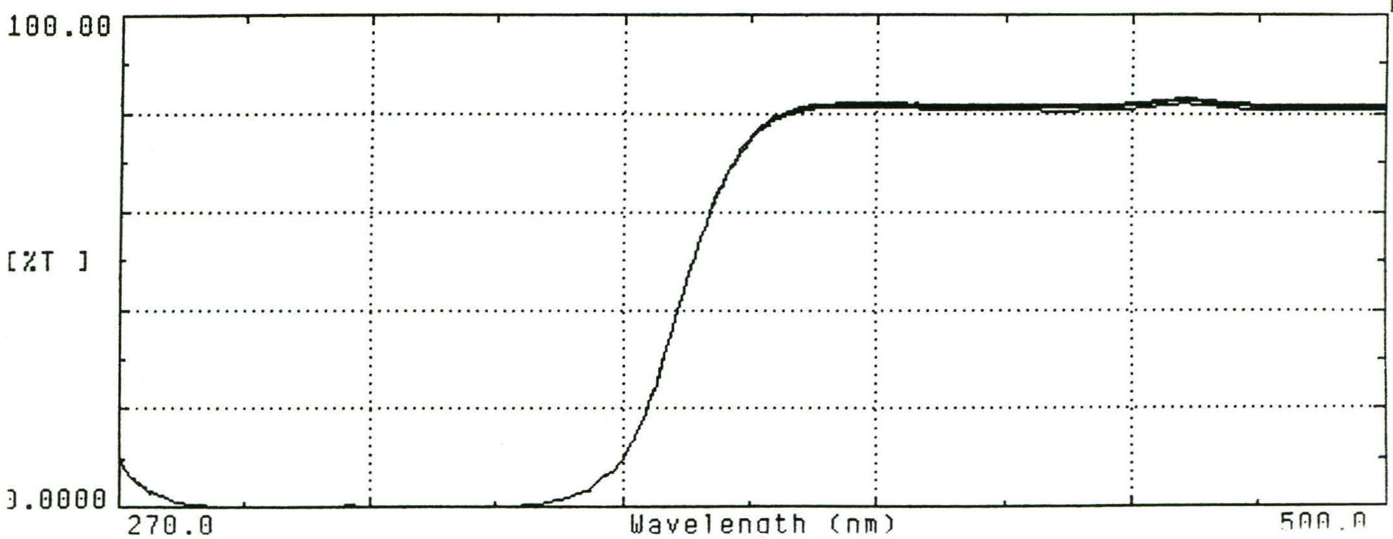
Acuvue 1-day (+6.00 DS)

Figure 17



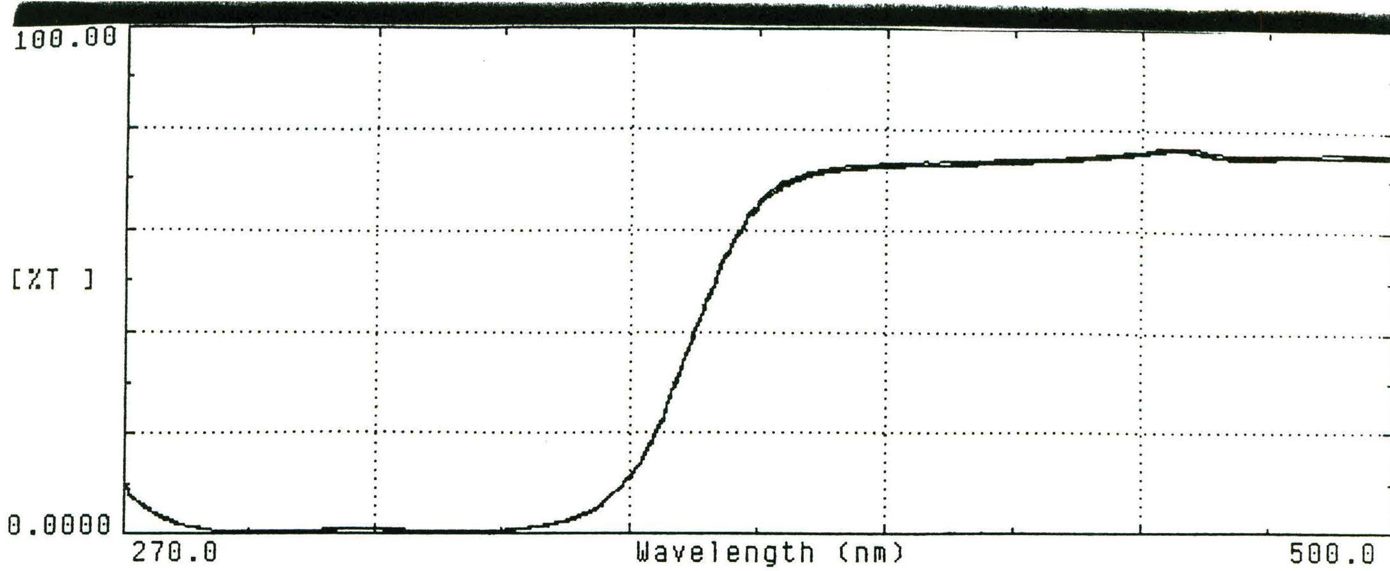
Acuvue 1-day (+3.00 DS)

Figure 18



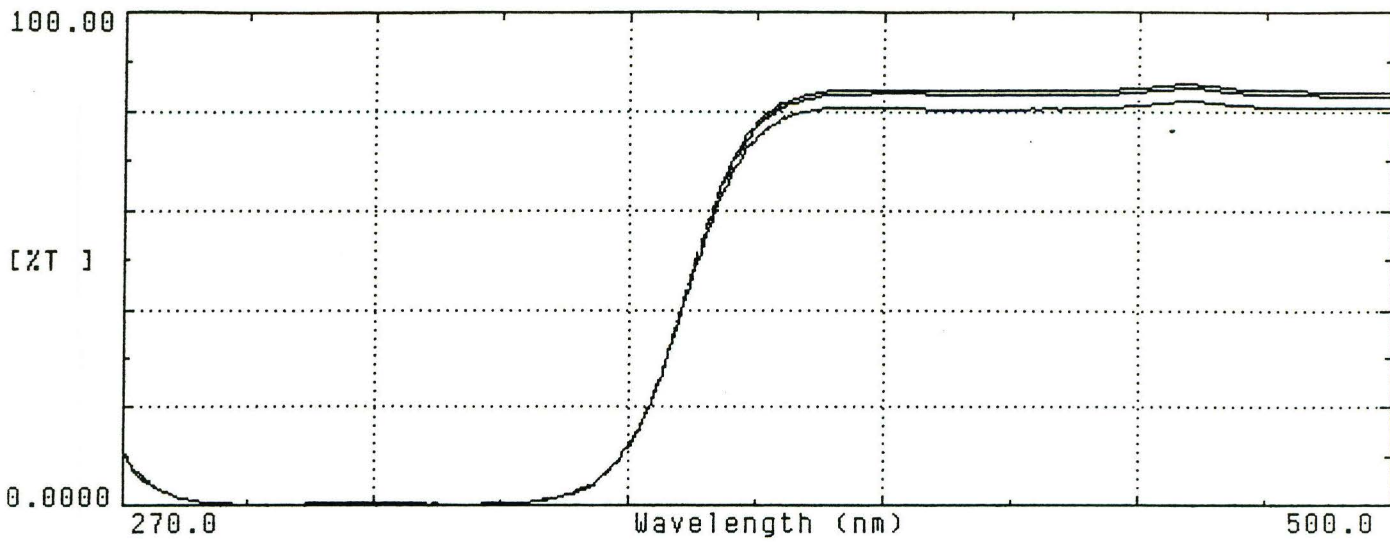
Acuvue 1-day (-3.00 DS)

Figure 19



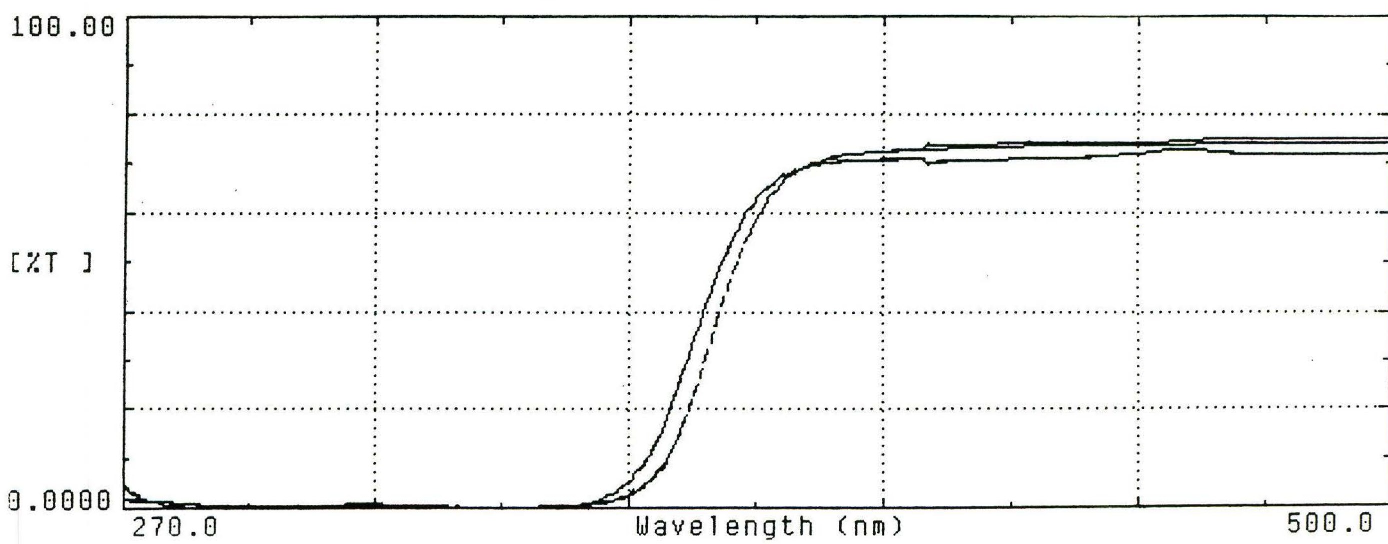
Surevue (+6.00 DS)

Figure 20



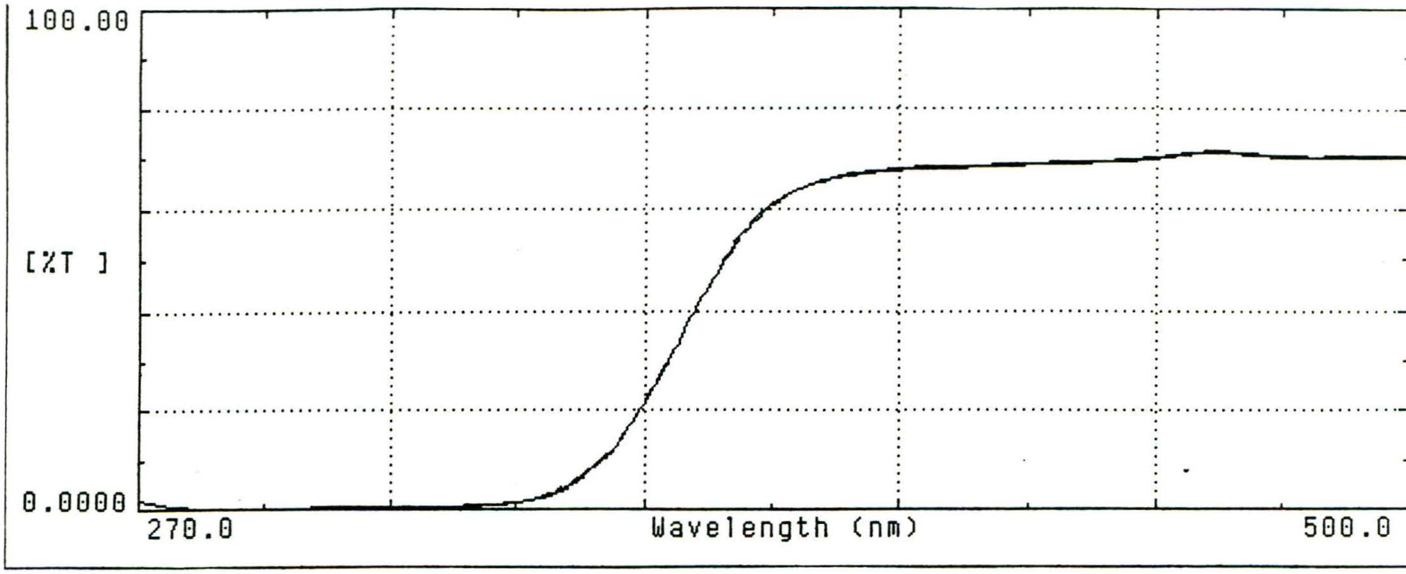
Surevue (+3.00 DS)

Figure 21



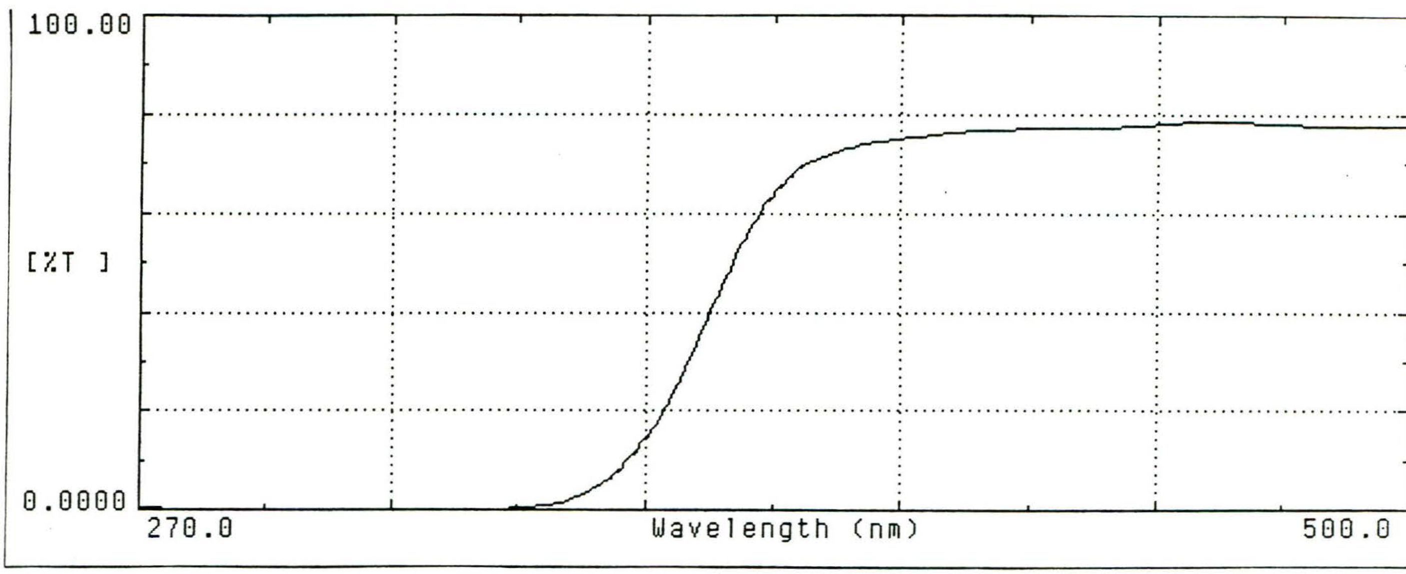
Surevue (-3.00 DS)

igure 22



Diagnostic Lens 60 (-3.00 DS)

igure 23



Diagnostic Lens 60 (-6.00 DS)

Table 3: Range of percent transmittance for soft contact lenses in this study

LENS TYPE	UV-TRANSMITTANCE (%)		
	UVA	UVB	UVC
Ciba Focus Monthly			
+6.00 DS	82.0-6.0	11.0-6.0	11.0-9.0
+3.00 DS	76.0-18.0	20.0-12.0	13.0
-3.00 DS	77.5-15.0	18.0-3.0	7.0-5.0
Precision UV			
+6.00 DS	63.0-0.0	1.0-0.0	2.0-1.0
+3.00 DS	75.0-2.0	5.0-2.0	7.0-5.5
-3.00 DS	64.0-1.0	2.0-1.0	3.5-2.5
Permaflex Naturals			
+3.25 DS	78.0-3.0	9.0-5.0	12.0-9.0
-3.25 DS	89.0-4.0	11.0-6.0	15.0-11.5
-6.00 DS	92.0-15.0	85.5-16.0	81.0-79.0
Acuvue 2			
+6.00 DS	81.0-4.0	9.0-5.0	14.0-10.0
+3.00 DS	92.0-1.0	1.0-0.0	8.0-1.5
-3.00 DS	67.0-0.0	1.0-0.0	2.5-1.5
Acuvue			
+6.00 DS	82.5-3.0	7.0-3.0	11.0-9.0
+3.00 DS	81.0-2.0	5.0-2.0	7.5-5.0
-3.00 DS	73.5-1.5	3.0-1.5	4.0-3.0
Acuvue 1-day			
+6.00 DS	71.3-9.0	13.0-8.0	16.0-14.0
+3.00 DS	75.0-65.0	67.0-64.0	64.0-63.5
-3.00 DS	82.0-0.0	1.0-0.0	10.0-1.5
Surevue			
+6.00 DS	73.0-1.0	2.0-1.0	9.5-2.0
+3.00 DS	72.5-0.0	1.0-0.0	10.0-1.5
-3.00 DS	71.0-0.0	1.0	5.0-1.0
Diagnostic Lens 60			
-3.00 DS	68.0-1.0	1.0-0.0	2.5-0.0
-6.00 DS	75.0-0.0	0.0	1.0-0.0

Table 4: ANSI Z80.20 Pass/Fail results for soft contact lenses in this study

Contact Lenses		**ANSI Z80.20 Results**	
Brand	**Power**	**UVA**	**UVB**
Ciba Focus Monthly	+6.00 D	Pass	Fail
	+3.00 D	Pass	Fail
	-3.00 D	Pass	Fail
Precision UV	+6.00 D	Pass	Pass
	+3.00 D	Pass	Pass
	-3.00 D	Pass	Pass
Permaflex UV Naturals	+3.25 D	Pass	Fail
	-3.25 D	Pass	Fail
	-6.00 D	Fail	Fail
Acuvue 2	+6.00 D	Pass	Fail
	+3.00 D	Pass	Pass
	-3.00 D	Pass	Fail
Acuvue	+6.00 D	Pass	Fail
	+3.00 D	Pass	Pass
	-3.00 D	Pass	Pass
Acuvue 1-Day			
	+6.00 D	Fail	Fail
	+3.00 D	Fail	Fail
	-3.00 D	Pass	Pass
Surevue	+6.00 D	Pass	Pass
	+3.00 D	Pass	Pass
	-3.00 D	Pass	Pass
Diagnostic Lens 60	-3.00 D	Pass	Pass
	-6.00 D	Pass	Pass

Discussion

Center thickness and UVR transmittance were compared between –3.00 D (thinner) and +3.00 D (thicker) lenses since the thickness of these specific powers was listed in Tyler's Quarterly. Comparisons were based on the range UV transmittance percentages listed in Table 3. Ciba Focus Monthly and Surevue resulted in similar transmission percentiles between the +3.00 D and –3.00 D for each brand. Precision UV resulted in slightly higher UVA transmission (11% higher) for the minus lens, but measurement error was possible for the plus lens. Permaflex UV Natural and Acuvue 1-Day demonstrated slightly higher UVA transmission (11% and 7% respectively) for the minus (thinner) lens. A 7% greater UVA transmittance was found for the –6.00 D compared to the –3.00 D lens. However, the center thickness for the –6.00 D Diagnostic Lens 60 is unknown. The Acuvue 2 and Acuvue lenses demonstrated greater UVA transmittance (25% and 7.5%) for the plus lenses (thicker).

Acuvue 1-day +3.00 D, Permaflex UV Natural –6.00 D, and Precision UV +3.00 D lenses transmitted a large percent of UVR amounts across the entire spectrum. This may have been related to experimenter error including poor positioning of the lens in the spectrophotometer, or dehydration and warping during the scanning process.

Before beginning our research, we hypothesized that the center thickness would have minimal effect on UVR transmittance since the UVR tint is covalently attached to the lens polymer matrix. However, this may be dependent upon which point in the manufacturing process the UV absorbing dye was added and extracted, either before or after the entire lens fabrication. This may account for small transmission differences between lens powers and between brands. No consistent pattern of UVR transmittance based on power and center thickness can be established since higher levels of transmittance are found in both thicker (plus) and thinner (minus) lenses.

While comparing the transmittance curves, one pattern was present. In most cases, the percent transmittance dropped significantly from 408 to 362 nm, the wavelength range affecting the retina the most. Precision UV offered the best, although not complete, UV absorption within this range. As stated earlier, the cornea is most sensitive to 270 nm. The contact lens brands giving the best protection at that wavelength included the Precision UV (+6.00 D), Acuvue2 (–3.00 D), Acuvue 1-day (-3.00 D), Surevue (+6.00 D, +3.00 D, -3.00 D), and Diagnostic Lens 60 (-3.00 D, -6.00 D). The crystalline lens is most sensitive to 300-320 nm and the Precision UV (+6.00 D, +3.00 D, -3.00 D), Acuvue2 (+3.00 D, -3.00 D), Acuvue 1-day (-3.00 D), Surevue (+6.00 D, +3.00 D, -3.00 D), and Diagnostic Lens 60 (-3.00 D, -6.00 D) offer the best protection. Of the UV blocking soft lenses, the Surevue and Diagnostic Lens 60 offered the most consistent protection across the spectrum with all parameters tested.

In order for the manufacturer to label a lens as having UV protection it must meet ANSI standard Z80.20 for Class 2 UV blockers allowing a maximum of 30% transmittance of UVA wavelengths and 5% of UVB wavelengths (Harris et al. 2000). Since visible light is defined as violet at 380 – 430 nm, UVA is frequently defined as 315 – 380 nm in research for UV-absorbing SCLs (Hickson-Curran 1997 and Harris 2000). The use of 380 nm might make it is easier to achieve the 30% transmittance limit of UVA.

An estimation was made using Figures 1 – 23 to determine if the SCLs passed or failed Z80.20 to 400 nm. The first column of 5 cells on the left of the transmission curve roughly estimates all UVB wavelengths (270 – 316 nm). A passing score was given if approximately 5 % or less of cells demonstrated UVB transmission. The second and third columns from the left side, a total of 10 cells, approximate all UVA wavelengths (316 – 408 nm). A passing score was given if approximately 30%, or 3 cells or less, demonstrated UVA transmittance. Measurement error is suspected in those lenses that failed both UVA and UVB criteria. Dehydration and warping may have caused lenses to fail the UVB portion, since this is the last of the wavelengths to be scanned in the spectrophotometer.

Moseley and Jones recommended the following guidelines, Table 5, for patients receiving photochemotherapy (PUVA). Unfortunately, none of the UV-absorbing contact lenses in this study meet these requirements. Physician should warn patients that SCLs labeled as UV are inadequate for this condition and special eyewear and/or a hat with a brim should be used in conjunction with any contact lenses.

Table 5: Transmission limits of lenses for use by PUVA patients

Wavelenth (nm)	Transmittance Limit %
390	10
380	5
370	2
360 & below	1

Current research has shown that acute and cumulative UVR exposure can lead to ocular and visual damage. It is important for practitioners to recommend contacts, spectacles, and hats in order to minimize adnexal, conjunctival, corneal, lenticular, and retinal UVR exposure. In particular, UVR protection is essential for patients with conditions such as aphakia, pseudophakia, aniridia, albinism, and patients using photosensitizing medications. It is also extremely important for those who work or play outdoors, and live in tropical or high altitude locations. Special attention should be paid to contact lens patients with the above conditions, and SCLs with UVR protection should be prescribed and used in conjunction with UV sunglasses and hats with brims.

The UV-absorbing SCLs evaluated in this study demonstrated some reduction in UVB and UVA, compared to the non-UV-absorbing control lens. ANSI standard Z80.20 was met by twelve of the 20 UV labeled SCLs. However the transmittance levels of SCLs allowed more UVB and UVA transmittance than CR-39, UV treated spectacles lenses. For the best ocular and adnexal UVR protection, contacts in conjunction with UVR sunglasses and/or a hat with a brim are recommended. It is evident that contact lens manufactures need to continue working on improving UV-absorbers for soft contact lenses.

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