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CIE S 014-2/E

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Colorimetry —

Part 2:
CIE standard illuminants

Colorimétrie —

Partie 2: Illuminants CIE normalisés

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

ISO 11664-2 was prepared as Standard CIE S 014-2/E by the International Commission on Illumination, which has been recognized by the ISO Council as an international standardizing body. It was adopted by ISO under a special procedure which requires approval by at least 75 % of the member bodes casting a vote, and is published as a joint ISO/CIE edition.

The International Commission on Illumination (abbreviated as CIE from its French title) is an organization devoted to international cooperation and exchange of information among its member countries on all matters relating to the science and art of lighting.

International Standard ISO 11664-2 was prepared by CIE Technical Committee 2-33 *Reformulation of CIE Standard Illuminants A and D65.*

ISO 11664-2 was initially published by ISO as ISO 10526:2007, and has subsequently been renumbered to be part 2 of the ISO 11664 series.

ISO 11664 consists of the following parts, under the general title *Colorimetry*:

— *Part 1: CIE standard colorimetric observers* [published previously as ISO 10527:2007, which has been cancelled]

— *Part 2: CIE standard illuminants* [published previously as ISO 10526:2007, which has been cancelled]

— *Part 4: CIE 1976 L*a*b* Colour space*

CIE S 014-2/E:2006

COMMISSION INTERNATIONALE DE L'ÉCLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION
INTERNATIONALE BELEUCHTUNGSKOMMISSION

Standard

Colorimetry - Part 2: CIE Standard Illuminants

Colorimétrie - Partie 2: Illuminants normalisés CIE

Farbmessung - Teil 2: CIE Normlichtarten

CIE Central Bureau, Vienna
Kegelgasse 27, A-1030 Vienna, Austria

CIE S 014-2/E:2006

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Standard colorimetric system

CIE Central Bureau
Kegelgasse 27
A-1030 Vienna
Austria
Tel.: +43 1 714 3187 0
Fax: +43 1 714 3187 18
e-mail: ciecb@ping.at
Web: www.cie.co.at/

FOREWORD

Standards produced by the Commission Internationale de l'Eclairage (CIE) are a concise documentation of data defining aspects of light and lighting, for which international harmony requires such unique definition. CIE Standards are therefore a primary source of internationally accepted and agreed data, which can be taken, essentially unaltered, into universal standard systems.

This CIE Standard replaces ISO 10526:1999/CIE S005:1998 and was approved by the CIE Board of Administration and the National Committees of the CIE. It contains only minor changes from the previous standard, which was prepared by CIE Technical Committee 2-33, "Reformulation of CIE Standard Illuminants A and D65" *).

The numerical values of the relative spectral distributions of standard illuminants A and D65 defined by this Standard are the same, within an accuracy of six significant digits, as those defined in earlier versions of these illuminants.

TABLE OF CONTENTS

*) Chairman of this TC was K. D. Mielenz (US), members were: J. J. Hsia (US), J. R. Moore (GB), A. R. Robertson (CA), H. Terstiege (DE) ✞, J. F. Verrill (GB) ✞.
This present revision was finalized by an editorial group in CIE Division 2: J. Gardner (AU), T. Goodman (UK), K. Mielenz (US), J. Moore (UK), Y. Ohno (US), A. Robertson (CA), J. Schanda (HU).

COLORIMETRY - PART 2: CIE STANDARD ILLUMINANTS

1. SCOPE

This International Standard specifies two illuminants for use in colorimetry. The illuminants, which are defined in clauses 4 and 5 of this International Standard, are as follows:

a) CIE standard illuminant A

This is intended to represent typical, domestic, tungsten-filament lighting. Its relative spectral power distribution is that of a Planckian radiator at a temperature of approximately 2 856 K. CIE standard illuminant A should be used in all applications of colorimetry involving the use of incandescent lighting, unless there are specific reasons for using a different illuminant.

b) CIE standard illuminant D65

This is intended to represent average daylight and has a correlated colour temperature of approximately 6 500 K. CIE standard illuminant D65 should be used in all colorimetric calculations requiring representative daylight, unless there are specific reasons for using a different illuminant. Variations in the relative spectral power distribution of daylight are known to occur, particularly in the ultraviolet spectral region, as a function of season, time of day, and geographic location. However, CIE standard illuminant D65 should be used pending the availability of additional information on these variations.

Values for the relative spectral power distribution of CIE standard illuminants A and D65 are given in Table 1 of this International Standard. Values are given at 1 nm intervals from 300 nm to 830 nm.

The term "illuminant" refers to a defined spectral power distribution, not necessarily realizable or provided by an artificial source. Illuminants are used in colorimetry to compute the tristimulus values of reflected or transmitted object colours under specified conditions of illumination. The CIE has also defined illuminant C and other illuminants D. These illuminants are described in Publication CIE 15:2004 but they do not have the status of primary CIE standards accorded to the CIE standard illuminants A and D65 described in this International Standard. It is recommended that one of the two CIE standard illuminants defined in this International Standard be used wherever possible. This will greatly facilitate the comparison of published results.

It is noted that in the fields of graphic arts and photography extensive use is also made of CIE illuminant D50.

In most practical applications of colorimetry, it is sufficient to use the values of CIE standard illuminants A and D65 at less frequent wavelength intervals or in a narrower spectral region than defined in this Standard. Data and guidelines that facilitate such practice are provided in Publication CIE 15:2004, together with other recommended procedures for practical colorimetry.

The term "source" refers to a physical emitter of light, such as a lamp or the sky. In certain cases, the CIE recommends laboratory sources that approximate the spectral power distributions of CIE illuminants. In all cases, however, the definition of a CIE recommended source is secondary to the definition of the corresponding CIE illuminant, because of the possibility that, from time to time, new developments will lead to improved sources that represent a particular illuminant more accurately or are more suitable for laboratory use.

Subclause 6.1 of this International Standard describes CIE source A, which is recommended for laboratory realizations of CIE standard illuminant A. At present, there is no CIE recommended source representing CIE standard illuminant D65.

2. NORMATIVE REFERENCES

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CIE 15:2004. *Colorimetry, 3rd edition.*

CIE 17.4-1987. *International Lighting Vocabulary* (ILV) - Joint publication IEC/CIE.

ISO 23603:2005/CIE S 012/E:2004. *Standard method of assessing the spectral quality of daylight simulators for visual appraisal and measurement of colour.*

CIE S 014-1/E:2006. *Colorimetry Part 1: CIE standard* colorimetric *observers. [ISO 11664-1:2007]*

3. DEFINITIONS

For the purposes of this International Standard, the following definitions apply. These definitions are taken from CIE 17.4-1987, where other relevant terms will also be found.

3.1 chromaticity coordinates (see ILV 845-03-33)

ratio of each of a set of three tristimulus values to their sum

NOTE 1: As the sum of the three chromaticity coordinates equals 1, two of them are sufficient to define a chromaticity.

NOTE 2: In the CIE 1931 and 1964 standard colorimetric systems, the chromaticity co-ordinates are represented by the symbols x, y, z and x_{10}, y_{10}, z_{10}.

3.2 chromaticity diagram (see ILV 845-03-35)

plane diagram in which points specified by chromaticity co-ordinates represent the chromaticities of colour stimuli

3.3 CIE standard illuminants

illuminants A and D65 defined by the CIE in terms of relative spectral power distributions [1]

3.4 CIE sources

artificial sources, specified by the CIE, whose relative spectral power distributions are approximately the same as those of CIE standard illuminants [1]

3.5 CIE 1976 uniform chromaticity scale diagram; CIE 1976 UCS diagram (see ILV 845-03-53)

uniform chromaticity scale diagram produced by plotting in rectangular co-ordinates v' against u', quantities defined by the equations

$$u' = 4X/(X + 15Y + 3Z) = 4x/(-2x + 12y + 3)$$

$$v' = 9Y/(X + 15Y + 3Z) = 9y/(-2x + 12y + 3)$$

X, Y, Z are the tristimulus values in the CIE 1931 or 1964 standard colorimetric systems, and x, y are the corresponding chromaticity coordinates of the colour stimulus considered.

3.6 colour temperature T_c (see ILV 845-03-49)

temperature of a Planckian radiator whose radiation has the same chromaticity as that of a given stimulus

[1] This definition is a revision of the definition given in CIE 17.4-1987.

3.7 correlated colour temperature T_{cp} (see CIE 15:2004 Section 9.5) [2]

temperature of a Planckian radiator having the chromaticity nearest the chromaticity associated with the given spectral distribution on a diagram where the (CIE 1931 standard observer based) u', 2/3v' coordinates of the Planckian locus [3] and the test stimulus are depicted

NOTE 1: The concept of correlated colour temperature should not be used if the chromaticity of the test source differs more than $\Delta C = [(u'_t - u'_P)^2 + \frac{4}{9} \cdot (v'_t - v'_P)^2]^{1/2} = 5 \times 10^{-2}$ from the Planckian radiator, where u'_t, v'_t refer to the test source, u'_P, v'_P to the Planckian radiator.

NOTE 2: Correlated colour temperature can be calculated by a simple minimum search computer program that searches for that Planckian temperature that provides the smallest chromaticity difference between the test chromaticity and the Planckian locus or by any other equivalent method. [4]

3.8 daylight illuminant (see ILV 845-03-11)

illuminant having the same, or nearly the same, relative spectral power distribution as a phase of daylight

3.9 illuminant (see ILV 845-03-10)

radiation with a relative spectral power distribution defined over the wavelength range that influences object colour perception

3.10 Planckian radiator; blackbody (see ILV 845-04-04)

ideal thermal radiator that absorbs completely all incident radiation, whatever the wavelength, the direction of incidence or the polarization. This radiator has, for any wavelength and any direction, the maximum spectral concentration of radiance for a thermal radiator in thermal equilibrium at a given temperature.

3.11 Planckian locus (see ILV 845-03-41)

locus of points in a chromaticity diagram that represents chromaticities of the radiation of Planckian radiators at different temperatures

3.12 primary light source (see ILV 845-07-01)

surface or object emitting light produced by a transformation of energy

3.13 secondary light source (see ILV 845-07-02)

surface or object which is not self-emitting but receives light and re-directs it, at least in part, by reflection or transmission

3.14 tristimulus values (of a colour stimulus) (see ILV 845-03-22)

amounts of the three reference colour stimuli, in a given trichromatic system, required to match the colour of the stimulus considered

NOTE: In the CIE standard colorimetric systems, the tristimulus values are represented by the symbols X, Y, Z and X_{10}, Y_{10}, Z_{10}.

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[2] This definition is a revision of the definition given in CIE 17.4-1987.

[3] In calculating the chromaticity coordinates of the Planckian radiator the c_2 value according to ITS-90 has to be used (c_2 = 1,4388) in Planck's equation for standard air, but assuming n=1.

[4] CIE 15:2004 suggests one possible method recommended by Robertson (1968).

4. CIE STANDARD ILLUMINANT A

4.1 Definition

The relative spectral power distribution $S_A(\lambda)$ is defined by the equation

$$S_A(\lambda) = 100\left(\frac{560}{\lambda}\right)^5 \times \frac{\exp\dfrac{1{,}435\times 10^7}{2\,848\times 560}-1}{\exp\dfrac{1{,}435\times 10^7}{2\,848\,\lambda}-1} \qquad (1)$$

where λ is the wavelength in nanometres and the numerical values in the two exponential terms are definitive constants originating from the first definition of Illuminant A in 1931.

This spectral power distribution is normalized to the value 100 (exactly) at the wavelength 560 nm (exactly).

CIE standard illuminant A is defined over the 300 nm to 830 nm spectral region.

NOTE 1: Table 1 provides the relative spectral power distribution of CIE standard illuminant A between 300 nm and 830 nm to six significant digits, at one nm intervals. For all practical purposes it suffices to use these tabulated values instead of the values calculated from equation 1.

NOTE 2: Despite the fact that equation 1 is based on Planck's equation for vacuum, the wavelengths are to be taken as being in standard air (dry air at 15ºC and 101325 Pa, containing 0,03% by volume of carbon dioxide). This makes CIE standard illuminant A compatible with other CIE colorimetric and photometric data.

4.2 Theoretical basis

Equation 1 is equivalent to and can be derived from the expression

$$S(\lambda) = 100\ M_{e,\lambda}(\lambda,T)\ /\ M_{e,\lambda}(560,\ T), \qquad (2)$$

where

$$M_{e,\lambda}(\lambda,T) = c_1\ \lambda^{-5}\ [\exp(c_2\ /\lambda T)\text{-}\ 1]^{-1}, \qquad (3)$$

λ is the wavelength (in nanometres), and the ratio $c_2\ /T$ is given by

$$c_2\ /T = 1{,}435 \text{ x } 10^7/\ 2\ 848 \text{ nm}. \qquad (4)$$

Since the numerical value of c_1 cancels out of equation 2, this definition of CIE standard illuminant A involves no assumptions about the numerical values of c_1, c_2, and T other than the ratio defined in equation 4.

4.3 Supplementary notes

CIE standard illuminant A was originally defined in 1931 (CIE, 1931) as the relative spectral power distribution of a Planckian radiator of temperature

$$T_{\text{CIE 1931}} = 2\ 848 \text{ K}, \qquad (5)$$

the value of the second radiation constant c_2 then being taken as

$$c_{2,\ \text{CIE 1931}} = 14\ 350\ \mu\text{m}\cdot\text{K}. \qquad (6)$$

This form of definition as given in equation 1 was carefully chosen to ensure that CIE standard illuminant A was defined as a relative spectral power distribution and not as a function of temperature. As explained in 4.2 above, the definition of the relative spectral power distribution has not changed since 1931 and equation 1 simply expresses it in a general form.

What has changed is the temperature assigned to this distribution. The value of c_2 given in equation 6 and used by the CIE in 1931 is different from the respective values, $c_{2,\ \text{ITS-27}}$ = 14 320 µm·K, $c_{2,\text{IPTS-48}}$ = 14 380 µm·K, and $c_{2,\text{IPTS-68}}$ = $c_{2,\text{ITS-90}}$ = 14 388 µm·K, that were assigned to this constant in the International Temperature Scales of 1927, 1948, 1968 and

1990. Although this has had no effect on the relative spectral power distribution of CIE standard illuminant A, the correlated colour temperatures of sources recommended for laboratory realizations have been different, over the years, depending on the values of c_2 used.

As may be seen from equation 4, the colour temperatures associated with CIE standard illuminant A on the various international temperature scales referred to above were T_{27} = 2 842 K, T_{48} = 2 854 K, and T_{68} = T_{90} = 2 856 K, respectively (see 6.1).

5. CIE STANDARD ILLUMINANT D65

5.1 Definition

The relative spectral power distribution $S_{D65}(\lambda)$ of CIE standard illuminant D65 is defined by the values given in Table 1 which are presented at 1 nm intervals over the wavelength range from 300 nm to 830 nm; the wavelength values given apply in standard air. If required, other intermediate values may be derived by linear interpolation from the published values. [5]

5.2 Experimental basis

The relative spectral power distribution of CIE standard illuminant D65 is based on experimental measurements of daylight in the wavelength range 330 nm to 700 nm, with extrapolations to 300 nm and 830 nm, as reported by Judd, MacAdam, and Wyszecki (Judd et al., 1964). The extrapolated values are believed to be sufficiently accurate for conventional colorimetric purposes, but are not recommended for non-colorimetric use.

5.3 Correlated colour temperature

CIE standard illuminant D65 has a nominal correlated colour temperature of 6 500 K. The exact value depends on the convention used to assign a correlated colour temperature to a stimulus whose chromaticity, as in this case, does not fall precisely on the Planckian locus.

NOTE: Using the value of c_2 = 14 388 μm·K specified in the International Temperature Scale of 1990 and the definition given in 3.7 that lines of constant correlated colour temperature are normal to the Planckian locus in a chromaticity diagram in which $2v'/3$ is plotted against u', where u', v' are the co-ordinates used in the CIE 1976 uniform chromaticity scale diagram, the correlated colour temperature of CIE standard illuminant D65 is found to be 6 503 K if it is computed according to the definition in 3.7 using the data of Table 1. This difference from the nominal temperature of the CIE standard illuminant was judged to be insignificantly small.

6. CIE SOURCES FOR PRODUCING CIE STANDARD ILLUMINANTS

6.1 CIE source A

CIE standard illuminant A can be realized by CIE source A, defined as a gas-filled, tungsten-filament lamp operating at a correlated colour temperature

$$T = \frac{2848\, c_2}{14350}\ \text{K} \qquad (7)$$

on a radiation temperature scale specified by a given value of the second radiation constant c_2 in μm·K. A lamp with a fused-quartz envelope or window is recommended if the spectral power distribution of the ultraviolet radiation of CIE standard illuminant A is to be realized more accurately.

[5] Information on the procedure used to derive D65 values is given in CIE 15:2004.

The value of c_2 specified in the International Temperature Scale of 1990 (ITS-90) is $c_{2,\text{ITS-90}}$ = 14 388 µm·K, and thus the correlated colour temperature of CIE source A on this scale is given by

$$T_{90} = \frac{14388}{14350} \times 2848\text{K} = 2856\text{K} \text{ (approximately)} \tag{8}$$

Sources calibrated on earlier temperature scales may have to be recalibrated in order to conform with the ITS-90.

This description of CIE source A is supplementary to, and not part of, the definition of CIE standard illuminant A.

6.2 Source for CIE standard illuminant D65

At present, there is no CIE recommended source for realizing CIE standard illuminant D65. The quality of sources intended for laboratory realization of CIE standard illuminant D65 can be assessed by a method described in ISO 23603:2005/CIE S012:2004. [6]

[6] CIE is studying recent developments in daylight simulators with a view to recommending a practical artificial source for CIE standard illuminant D65 in the near future. Readers of this standard should consult CIE Publication Lists for possible amendments and new recommendations.

TABLE 1. RELATIVE SPECTRAL POWER DISTRIBUTIONS OF CIE STANDARD ILLUMINANTS A AND D65 (wavelengths in standard air).

λ / nm	$S_A(\lambda)$	$S_{D65}(\lambda)$
300	0,930 483	0,0341 000
301	0,967 643	0,360 140
302	1,005 97	0,686 180
303	1,045 49	1,012 22
304	1,086 23	1,338 26
305	1,128 21	1,664 30
306	1,171 47	1,990 34
307	1,216 02	2,316 38
308	1,261 88	2,642 42
309	1,309 10	2,968 46
310	1,357 69	3,294 50
311	1,407 68	4,988 65
312	1,459 10	6,682 80
313	1,511 98	8,376 95
314	1,566 33	10,071 1
315	1,622 19	11,765 2
316	1,679 59	13,459 4
317	1,738 55	15,153 5
318	1,799 10	16,847 7
319	1,861 27	18,541 8
320	1,925 08	20,236 0
321	1,990 57	21,917 7
322	2,057 76	23,599 5
323	2,126 67	25,281 2
324	2,197 34	26,963 0
325	2,269 80	28,644 7
326	2,344 06	30,326 5
327	2,420 17	32,008 2
328	2,498 14	33,690 0
329	2,578 01	35,371 7
330	2,659 81	37,053 5
331	2,743 55	37,343 0
332	2,829 28	37,632 6
333	2,917 01	37,922 1
334	3,006 78	38,211 6
335	3,098 61	38,501 1
336	3,192 53	38,790 7
337	3,288 57	39,080 2
338	3,386 76	39,369 7
339	3,487 12	39,659 3
340	3,589 68	39,948 8
341	3,694 47	40,445 1
342	3,801 52	40,941 4
343	3,910 85	41,437 7
344	4,022 50	41,934 0
345	4,136 48	42,430 2
346	4,252 82	42,926 5
347	4,371 56	43,422 8
348	4,492 72	43,919 1
349	4,616 31	44,415 4

λ / nm	$S_A(\lambda)$	$S_{D65}(\lambda)$
350	4,742 38	44,911 7
351	4,870 95	45,084 4
352	5,002 04	45,257 0
353	5,135 68	45,429 7
354	5,271 89	45,602 3
355	5,410 70	45,775 0
356	5,552 13	45,947 7
357	5,696 22	46,120 3
358	5,842 98	46,293 0
359	5,992 44	46,465 6
360	6,144 62	46,638 3
361	6,299 55	47,183 4
362	6,457 24	47,728 5
363	6,617 74	48,273 5
364	6,781 05	48,818 6
365	6,947 20	49,363 7
366	7,116 21	49,908 8
367	7,288 11	50,453 9
368	7,462 92	50,998 9
369	7,640 66	51,544 0
370	7,821 35	52,089 1
371	8,005 01	51,877 7
372	8,191 67	51,666 4
373	8,381 34	51,455 0
374	8,574 04	51,243 7
375	8,769 80	51,032 3
376	8,968 64	50,820 9
377	9,170 56	50,609 6
378	9,375 61	50,398 2
379	9,583 78	50,186 9
380	9,795 10	49,975 5
381	10,009 6	50,442 8
382	10,227 3	50,910 0
383	10,448 1	51,377 3
384	10,672 2	51,844 6
385	10,899 6	52,311 8
386	11,130 2	52,779 1
387	11,364 0	53,246 4
388	11,601 2	53,713 7
389	11,841 6	54,180 9
390	12,085 3	54,648 2
391	12,332 4	57,458 9
392	12,582 8	60,269 5
393	12,836 6	63,080 2
394	13,093 8	65,890 9
395	13,354 3	68,701 5
396	13,618 2	71,512 2
397	13,885 5	74,322 9
398	14,156 3	77,133 6
399	14,430 4	79,944 2

TABLE 1 (*continued*)

λ / nm	$S_A(\lambda)$	$S_{D65}(\lambda)$
400	14,708 0	82,754 9
401	14,989 1	83,628 0
402	15,273 6	84,501 1
403	15,561 6	85,374 2
404	15,853 0	86,247 3
405	16,148 0	87,120 4
406	16,446 4	87,993 6
407	16,748 4	88,866 7
408	17,053 8	89,739 8
409	17,362 8	90,612 9
410	17,675 3	91,486 0
411	17,991 3	91,680 6
412	18,310 8	91,875 2
413	18,633 9	92,069 7
414	18,960 5	92,264 3
415	19,290 7	92,458 9
416	19,624 4	92,653 5
417	19,961 7	92,848 1
418	20,302 6	93,042 6
419	20,647 0	93,237 2
420	20,995 0	93,431 8
421	21,346 5	92,756 8
422	21,701 6	92,081 9
423	22,060 3	91,406 9
424	22,422 5	90,732 0
425	22,788 3	90,057 0
426	23,157 7	89,382 1
427	23,530 7	88,707 1
428	23,907 2	88,032 2
429	24,287 3	87,357 2
430	24,670 9	86,682 3
431	25,058 1	88,500 6
432	25,448 9	90,318 8
433	25,843 2	92,137 1
434	26,241 1	93,955 4
435	26,642 5	95,773 6
436	27,047 5	97,591 9
437	27,456 0	99,410 2
438	27,868 1	101,228
439	28,283 6	103,047
440	28,702 7	104,865
441	29,125 3	106,079
442	29,551 5	107,294
443	29,981 1	108,508
444	30,414 2	109,722
445	30,850 8	110,936
446	31,290 9	112,151
447	31,734 5	113,365
448	32,181 5	114,579
449	32,632 0	115,794

λ / nm	$S_A(\lambda)$	$S_{D65}(\lambda)$
450	33,085 9	117,008
451	33,543 2	117,088
452	34,004 0	117,169
453	34,468 2	117,249
454	34,935 8	117,330
455	35,406 8	117,410
456	35,881 1	117,490
457	36,358 8	117,571
458	36,839 9	117,651
459	37,324 3	117,732
460	37,812 1	117,812
461	38,303 1	117,517
462	38,797 5	117,222
463	39,295 1	116,927
464	39,796 0	116,632
465	40,300 2	116,336
466	40,807 6	116,041
467	41,318 2	115,746
468	41,832 0	115,451
469	42,349 1	115,156
470	42,869 3	114,861
471	43,392 6	114,967
472	43,919 2	115,073
473	44,448 8	115,180
474	44,981 6	115,286
475	45,517 4	115,392
476	46,056 3	115,498
477	46,598 3	115,604
478	47,143 3	115,711
479	47,691 3	115,817
480	48,242 3	115,923
481	48,796 3	115,212
482	49,353 3	114,501
483	49,913 2	113,789
484	50,476 0	113,078
485	51,041 8	112,367
486	51,610 4	111,656
487	52,181 8	110,945
488	52,756 1	110,233
489	53,333 2	109,522
490	53,913 2	108,811
491	54,495 8	108,865
492	55,081 3	108,920
493	55,669 4	108,974
494	56,260 3	109,028
495	56,853 9	109,082
496	57,450 1	109,137
497	58,048 9	109,191
498	58,650 4	109,245
499	59,254 5	109,300

TABLE 1 (*continued*)

λ / nm	$S_A(\lambda)$	$S_{D65}(\lambda)$
500	59,861 1	109,354
501	60,470 3	109,199
502	61,082 0	109,044
503	61,696 2	108,888
504	62,312 8	108,733
505	62,932 0	108,578
506	63,553 5	108,423
507	64,177 5	108,268
508	64,803 8	108,112
509	65,432 5	107,957
510	66,063 5	107,802
511	66,696 8	107,501
512	67,332 4	107,200
513	67,970 2	106,898
514	68,610 2	106,597
515	69,252 5	106,296
516	69,896 9	105,995
517	70,543 5	105,694
518	71,192 2	105,392
519	71,843 0	105,091
520	72,495 9	104,790
521	73,150 8	105,080
522	73,807 7	105,370
523	74,466 6	105,660
524	75,127 5	105,950
525	75,790 3	106,239
526	76,455 1	106,529
527	77,121 7	106,819
528	77,790 2	107,109
529	78,460 5	107,399
530	79,132 6	107,689
531	79,806 5	107,361
532	80,482 1	107,032
533	81,159 5	106,704
534	81,838 6	106,375
535	82,519 3	106,047
536	83,201 7	105,719
537	83,885 6	105,390
538	84,571 2	105,062
539	85,258 4	104,733
540	85,947 0	104,405
541	86,637 2	104,369
542	87,328 8	104,333
543	88,021 9	104,297
544	88,716 5	104,261
545	89,412 4	104,225
546	90,109 7	104,190
547	90,808 3	104,154
548	91,508 2	104,118
549	92,209 5	104,082

λ / nm	$S_A(\lambda)$	$S_{D65}(\lambda)$
550	92,912 0	104,046
551	93,615 7	103,641
552	94,320 6	103,237
553	95,026 7	102,832
554	95,733 9	102,428
555	96,442 3	102,023
556	97,151 8	101,618
557	97,862 3	101,214
558	98,573 9	100,809
559	99,286 4	100,405
560	100,000	100,000
561	100,715	99,633 4
562	101,430	99,266 8
563	102,146	98,900 3
564	102,864	98,533 7
565	103,582	98,167 1
566	104,301	97,800 5
567	105,020	97,433 9
568	105,741	97,067 4
569	106,462	96,700 8
570	107,184	96,334 2
571	107,906	96,279 6
572	108,630	96,225 0
573	109,354	96,170 3
574	110,078	96,115 7
575	110,803	96,061 1
576	111,529	96,006 5
577	112,255	95,951 9
578	112,982	95,897 2
579	113,709	95,842 6
580	114,436	95,788 0
581	115,164	95,077 8
582	115,893	94,367 5
583	116,622	93,657 3
584	117,351	92,947 0
585	118,080	92,236 8
586	118,810	91,526 6
587	119,540	90,816 3
588	120,270	90,106 1
589	121,001	89,395 8
590	121,731	88,685 6
591	122,462	88,817 7
592	123,193	88,949 7
593	123,924	89,081 8
594	124,655	89,213 8
595	125,386	89,345 9
596	126,118	89,478 0
597	126,849	89,610 0
598	127,58	89,742 1
599	128,312	89,874 1

TABLE 1 (*continued*)

λ / nm	$S_A(\lambda)$	$S_{D65}(\lambda)$	λ / nm	$S_A(\lambda)$	$S_{D65}(\lambda)$
600	129,043	90,006 2	650	165,028	80,026 8
601	129,774	89,965 5	651	165,726	80,045 6
602	130,505	89,924 8	652	166,424	80,064 4
603	131,236	89,884 1	653	167,121	80,083 1
604	131,966	89,843 4	654	167,816	80,101 9
605	132,697	89,802 6	655	168,510	80,120 7
606	133,427	89,761 9	656	169,203	80,139 5
607	134,157	89,721 2	657	169,895	80,158 3
608	134,887	89,680 5	658	170,586	80,177 0
609	135,617	89,639 8	659	171,275	80,195 8
610	136,346	89,599 1	660	171,963	80,214 6
611	137,075	89,409 1	661	172,650	80,420 9
612	137,804	89,219 0	662	173,335	80,627 2
613	138,532	89,029 0	663	174,019	80,833 6
614	139,260	88,838 9	664	174,702	81,039 9
615	139,988	88,648 9	665	175,383	81,246 2
616	140,715	88,458 9	666	176,063	81,452 5
617	141,441	88,268 8	667	176,741	81,658 8
618	142,167	88,078 8	668	177,419	81,865 2
619	142,893	87,888 7	669	178,094	82,071 5
620	143,618	87,698 7	670	178,769	82,277 8
621	144,343	87,257 7	671	179,441	81,878 4
622	145,067	86,816 7	672	180,113	81,479 1
623	145,790	86,375 7	673	180,783	81,079 7
624	146,513	85,934 7	674	181,451	80,680 4
625	147,235	85,493 6	675	182,118	80,281 0
626	147,957	85,052 6	676	182,783	79,881 6
627	148,678	84,611 6	677	183,447	79,482 3
628	149,398	84,170 6	678	184,109	79,082 9
629	150,117	83,729 6	679	184,770	78,683 6
630	150,836	83,288 6	680	185,429	78,284 2
631	151,554	83,329 7	681	186,087	77,427 9
632	152,271	83,370 7	682	186,743	76,571 6
633	152,988	83,411 8	683	187,397	75,715 3
634	153,704	83,452 8	684	188,050	74,859 0
635	154,418	83,493 9	685	188,701	74,002 7
636	155,132	83,535 0	686	189,350	73,146 5
637	155,845	83,576 0	687	189,998	72,290 2
638	156,558	83,617 1	688	190,644	71,433 9
639	157,269	83,658 1	689	191,288	70,577 6
640	157,979	83,699 2	690	191,931	69,721 3
641	158,689	83,332 0	691	192,572	69,910 1
642	159,397	82,964 7	692	193,211	70,098 9
643	160,104	82,597 5	693	193,849	70,287 6
644	160,811	82,230 2	694	194,484	70,476 4
645	161,516	81,863 0	695	195,118	70,665 2
646	162,221	81,495 8	696	195,750	70,854 0
647	162,924	81,128 5	697	196,381	71,042 8
648	163,626	80,761 3	698	197,009	71,231 5
649	164,327	80,394 0	699	197,636	71,420 3

TABLE 1 (*continued*)

λ / nm	$S_A(\lambda)$	$S_{D65}(\lambda)$	λ / nm	$S_A(\lambda)$	$S_{D65}(\lambda)$
700	198,261	71,609 1	750	227,000	63,592 7
701	198,884	71,883 1	751	227,522	61,875 2
702	199,506	72,157 1	752	228,041	60,157 8
703	200,125	72,431 1	753	228,558	58,440 3
704	200,743	72,705 1	754	229,073	56,722 9
705	201,359	72,979 0	755	229,585	55,005 4
706	201,972	73,253 0	756	230,096	53,288 0
707	202,584	73,527 0	757	230,604	51,570 5
708	203,195	73,801 0	758	231,110	49,853 1
709	203,803	74,075 0	759	231,614	48,135 6
710	204,409	74,349 0	760	232,115	46,418 2
711	205,013	73,074 5	761	232,615	48,456 9
712	205,616	71,800 0	762	233,112	50,495 6
713	206,216	70,525 5	763	233,606	52,534 4
714	206,815	69,251 0	764	234,099	54,573 1
715	207,411	67,976 5	765	234,589	56,611 8
716	208,006	66,702 0	766	235,078	58,650 5
717	208,599	65,427 5	767	235,564	60,689 2
718	209,189	64,153 0	768	236,047	62,728 0
719	209,778	62,878 5	769	236,529	64,766 7
720	210,365	61,604 0	770	237,008	66,805 4
721	210,949	62,432 2	771	237,485	66,463 1
722	211,532	63,260 3	772	237,959	66,120 9
723	212,112	64,088 5	773	238,432	65,778 6
724	212,691	64,916 6	774	238,902	65,436 4
725	213,268	65,744 8	775	239,370	65,094 1
726	213,842	66,573 0	776	239,836	64,751 8
727	214,415	67,401 1	777	240,299	64,409 6
728	214,985	68,229 3	778	240,760	64,067 3
729	215,553	69,057 4	779	241,219	63,725 1
730	216,120	69,885 6	780	241,675	63,382 8
731	216,684	70,405 7	781	242,130	63,474 9
732	217,246	70,925 9	782	242,582	63,567 0
733	217,806	71,446 0	783	243,031	63,659 2
734	218,364	71,966 2	784	243,479	63,751 3
735	218,920	72,486 3	785	243,924	63,843 4
736	219,473	73,006 4	786	244,367	63,935 5
737	220,025	73,526 6	787	244,808	64,027 6
738	220,574	74,046 7	788	245,246	64,119 8
739	221,122	74,566 9	789	245,682	64,211 9
740	221,667	75,087 0	790	246,116	64,304 0
741	222,210	73,937 6	791	246,548	63,818 8
742	222,751	72,788 1	792	246,977	63,333 6
743	223,290	71,638 7	793	247,404	62,848 4
744	223,826	70,489 3	794	247,829	62,363 2
745	224,361	69,339 8	795	248,251	61,877 9
746	224,893	68,190 4	796	248,671	61,392 7
747	225,423	67,041 0	797	249,089	60,907 5
748	225,951	65,891 6	798	249,505	60,422 3
749	226,477	64,742 1	799	249,918	59,937 1

TABLE 1 (*continued*)

λ / nm	$S_A(\lambda)$	$S_{D65}(\lambda)$
800	250,329	59,451 9
801	250,738	58,702 6
802	251,144	57,953 3
803	251,548	57,204 0
804	251,950	56,454 7
805	252,350	55,705 4
806	252,747	54,956 2
807	253,142	54,206 9
808	253,535	53,457 6
809	253,925	52,708 3
810	254,314	51,959 0
811	254,700	52,507 2
812	255,083	53,055 3
813	255,465	53,603 5
814	255,844	54,151 6
815	256,221	54,699 8

λ / nm	$S_A(\lambda)$	$S_{D65}(\lambda)$
816	256,595	55,248 0
817	256,968	55,796 1
818	257,338	56,344 3
819	257,706	56,892 4
820	258,071	57,440 6
821	258,434	57,727 8
822	258,795	58,015 0
823	259,154	58,302 2
824	259,511	58,589 4
825	259,865	58,876 5
826	260,217	59,163 7
827	260,567	59,450 9
828	260,914	59,738 1
829	261,259	60,025 3
830	261,602	60,312 5

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