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**Raw optical glass — Vocabulary**

*Verre d'optique brut — Vocabulaire*



Reference number  
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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 3, *Optical materials and components*.

This second edition cancels and replaces the first edition (ISO 9802:1996), which has been technically revised.

The main changes are as follows:

- Updates and additions in the terms and definitions clause.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

# Raw optical glass — Vocabulary

## 1 Scope

This document defines terms relating to raw optical glass and related manufacturing processes. The list is not complete and only comprises those terms for which the definition is considered necessary for correct and adequate understanding of the terminology.

It is understood that the interpretations given are those corresponding to the practical usage in this field and that they do not necessarily coincide with those used in other fields.

## 2 Normative references

There are no normative references in this document.

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

### 3.1 General terms

#### 3.1.1

#### **light beam**

#### **beam**

bundle of rays

Note 1 to entry: It may consist of parallel, converging or diverging rays.

#### 3.1.2

#### **light ray**

#### **ray**

line perpendicular to the wavefronts of waves of light indicating its direction of propagation

Note 1 to entry: This definition assumes the common case of light propagating in an isotropic medium and not in caustic regions.

#### 3.1.3

#### **electromagnetic radiation**

energy that emanates from a source in the form of electromagnetic waves or photons and is transferred through space

Note 1 to entry: The term “electromagnetic radiation” is also used for the phenomenon producing the electromagnetic waves or photons (see IEV 702-02-07).

Note 2 to entry: The physical concepts of photons and electromagnetic waves are used to describe the same phenomenon of transmission of radiant energy in different ways, depending on the nature of the interaction of the energy with the physical world (wave-particle dualism).

Note 3 to entry: The French term “radiation électromagnétique” applies preferably to a single element of any electromagnetic radiation, characterized by one frequency or by one wavelength in vacuum.

[SOURCE: IEV 705-02-01]

### 3.1.3.1

#### **optical radiation**

electromagnetic radiation at wavelengths between the region of transition to X-rays ( $\lambda \approx 1$  nm) and the region of transition to radio waves ( $\lambda \approx 1$  mm)

Note 1 to entry: For the purposes of this document, only optical radiation from the vacuum ultraviolet (100 nm) to the mid-infrared (50  $\mu$ m) is considered.

[SOURCE: CIE S 017:2020, 17-21-002/IEV 845-21-002, modified — Deletion of Notes 1 and 2 to entry.]

### 3.1.3.1.1

#### **visible radiation**

optical radiation capable of causing a visual sensation directly

Note 1 to entry: There are no precise limits for the spectral range of visible radiation since they depend upon the amount of radiant flux reaching the retina and the responsivity of the observer. The lower limit is generally taken between 360 nm and 400 nm and the upper limit between 760 nm and 830 nm.

[SOURCE: IEV 845-21-003, modified — Deletion of Note 2 to entry that refer to the term numbers in previous editions.]

### 3.1.3.1.2

#### **infrared radiation**

IR radiation

IRR

optical radiation for which the wavelengths are longer than those of visible radiation

Note 1 to entry: For infrared radiation, the band from 780 nm to 50  $\mu$ m is typically broken up into:

IR-A 780 nm to 1,4  $\mu$ m;

IR-B 1,4  $\mu$ m to 3  $\mu$ m;

IR-C(MIR) 3  $\mu$ m to 50  $\mu$ m.

Note 2 to entry: See ISO 20473:2007 Table 1.

### 3.1.3.1.3

#### **ultraviolet radiation**

UV radiation

UVR

optical radiation for which the wavelengths are shorter than those of visible radiation

Note 1 to entry: For ultraviolet radiation, the range between 100 nm and 400 nm is commonly subdivided into:

UV-A 315 nm to 400 nm;

UV-B 280 nm to 315 nm;

UV-C 100 nm to 280 nm.

Note 2 to entry: For the purposes of this document, the upper limit for UV-A is 380 nm.

[SOURCE: IEV 845-21-008, modified — Deletion of Notes to entry 2 to 5 and the addition of a new Note 2 to entry.]

### 3.1.4

#### **spectrum**

display or specification of the monochromatic components of the radiation considered

Note 1 to entry: These are line spectra, continuous spectra and spectra exhibiting both of these characteristics.

Note 2 to entry: The term “spectrum” is also used for spectral efficiencies (excitation spectrum, action spectrum).  
 [SOURCE: IEV 845-21-015]

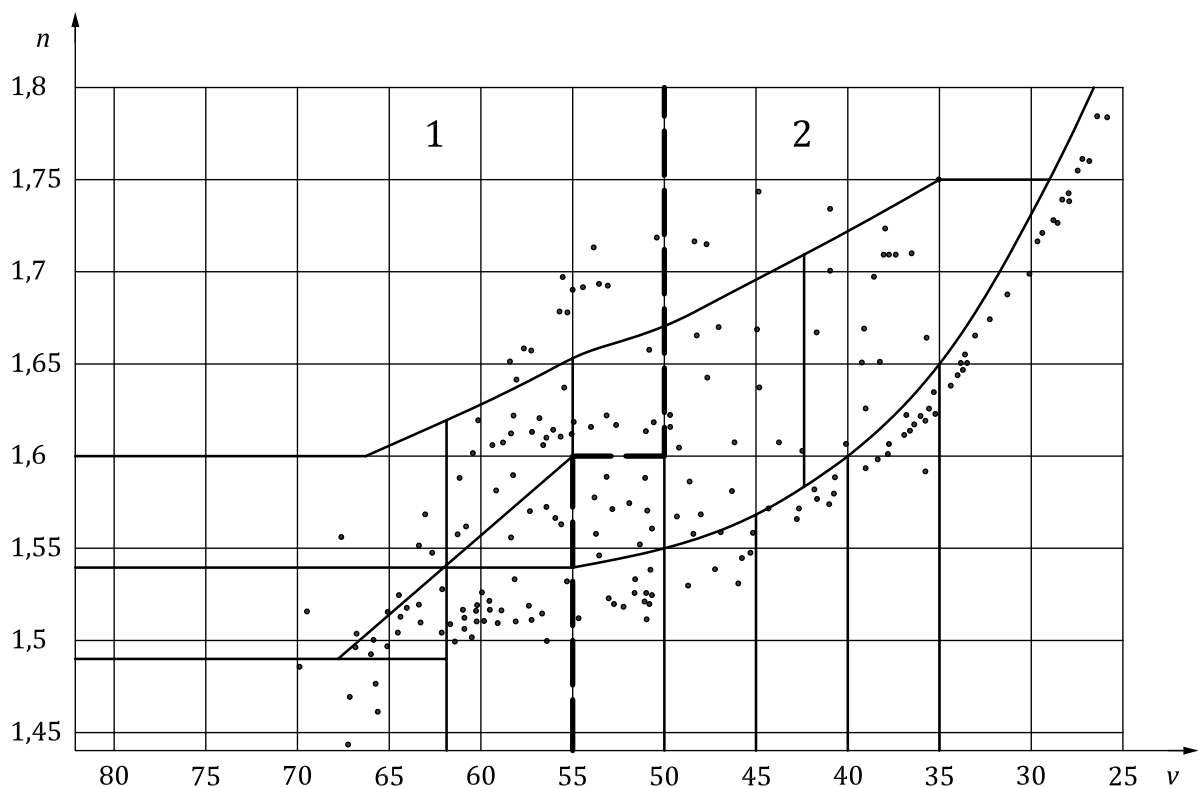
### 3.2 Type of optical glasses

#### 3.2.1

##### raw optical glass

inorganic product, usually obtained after melting, cooling and annealing without crystallization; including the solid state glass before production and the glass strip obtained in production; which is to a large extent free from imperfections such as bubbles, knots, stones and inhomogeneities such as striae and strains; which is characterized by specified optical properties such as refractive indices and dispersion; and dispersion and transparent to at least a part of the spectrum of light

Note 1 to entry: Optical glasses are classified into glass-groups according to their position in the refractive index Abbe number diagram. The main groups are crown glasses and flint glasses (see [Figure 1](#)).



##### Key

$v$	Abbe number	1	crown glasses
$n$	refractive index	2	flint glasses
		Dashed line	boundary between crown glass and flint glass

**Figure 1 — Refractive index Abbe number diagram**

#### 3.2.2

##### glass type

glass type letter/number designation used in the manufacturer's catalogue to designate or characterize the glasses offered

Note 1 to entry: An alphanumeric designation is the manufacturer's option and is usually a proprietary trade name, and therefore indeterminate. For example, borosilicate crown glass is designated N-BK by one manufacturer, but S-BSL and BSC by others.

Note 2 to entry: An alternative way to specify a glass type is the glass code (defined in [3.2.3](#)).

[SOURCE: ISO 12123:2018, 3.8, modified — Note 2 to entry was replaced.]

### 3.2.2.1

#### **crown glass**

optical glass type with an Abbe number greater than 55 for glasses with refractive indices less than 1,60 or with an Abbe number greater than 50 for glasses with refractive indices greater than 1,60

### 3.2.2.2

#### **flint glass**

optical glass type with an Abbe number less than 50 for glasses with refractive indices greater than 1,60 and with an Abbe number less than 55 for glasses with refractive indices less than 1,60

### 3.2.3

#### **glass code**

six-digit number representing the refractive index and Abbe number of a glass

Note 1 to entry: The first three digits represent the three decimal places of the refractive index, and the last three digits represent the upper three digits of Abbe number. For N-BK7 e.g. it is 517642. This glass code, however, does not denominate a glass type unequivocally. The same glass code can be valid for glass types of very different chemical compositions and hence other properties can also differ very significantly.

## 3.3 Process and media for fabrication and surface treatment

### 3.3.1

#### **slumping**

deformation of a glass piece under its own weight at high temperatures

### 3.3.2

#### **pressing**

forming glass to a shape close to that of a final product, by reheating and applying a load

Note 1 to entry: The final product can be, for example, a lens, a prism, a rod and etc.

### 3.3.3

#### **moulding**

shaping of a glass piece with tools under pressure at high temperatures

### 3.3.4

#### **annealing**

heat-treatment process in which the refractive index of glass is stabilized at a value close to its desired value, and in which the birefringence is minimized by holding the glass for specified periods of time at a temperature near its annealing point and subsequently cooling the glass at a specified rate to make it strain-free

### 3.3.5

#### **generating**

roughing process whereby glass is removed quickly in order to produce a surface form close to that required for its final form

### 3.3.6

#### **surfacing**

process of grinding, lapping and polishing a surface of an optical element

### 3.3.7

#### **grinding**

process in the fabrication of an optical element whereby optical glass is mechanically removed using bonded abrasives in order to reduce surface roughness



**3.3.8****lapping**

process in the fabrication of an optical element whereby optical glass is mechanically removed using loose abrasives in order to reduce surface roughness

**3.3.9****polishing**

process of generating a smooth and shiny surface without visible roughness of an optical element

Note 1 to entry: The treatment of the glass surface by either mechanical, chemical, thermal or any combination of processes can result in such shine.

**3.3.10****chamfering**

process of removing sharp edges by grinding or polishing

**3.3.11****edging**

finishing process of the edge of an optical element using a grinding wheel

**3.3.12****etching**

removal of the upper layers of a glass surface by dissolving in chemical agents, normally acids or by bombardment with energetic ions or neutral particles

**3.3.13****leaching**

extraction of mobile (soluble) constituents from a glass body by chemical reactions, preferably by aqueous solution

**3.3.14****ultrasonic cleaning**

cleaning of optical surfaces in a liquid by means of ultrasonic force

**3.3.15****abrasive**

media such as diamond, silica, silicon carbide, emery, cerium oxide, zirconia or rouge used in the optical industry for grinding or polishing of optical elements

Note 1 to entry: The media can be divided into loose abrasive and bonded or bound abrasive.

**3.3.16****pellet**

bonded abrasive such as diamond or boron carbide

**3.3.17****detergent**

synthetic liquid or solid substance, containing small amounts of an organic surface active agent and larger amounts of an inorganic builder, normally polyphosphates

Note 1 to entry: It can also contain monophosphate, sodium carbonate, sodium hydrogen carbonate and etc. It is dissolved in water and used for cleaning surfaces, particularly of glass.

### 3.4 Optical properties

#### 3.4.1

##### refraction

process by which the direction of propagation of an electromagnetic wave is changed as a result of changes in its velocity of propagation in passing through an optically non-homogeneous medium, or in crossing a surface separating media with different refractive indexes

[SOURCE: IEV 845-24-108, modified — Deletion of four Notes to entry and the addition of two Notes to entry.]

#### 3.4.2

##### refractive index

$n(\lambda)$

ratio of the velocity of the electromagnetic waves in vacuum to the phase velocity of the waves of the monochromatic radiation in the medium

Note 1 to entry: For technical applications, the refractive index in air is given instead of the refractive index in a vacuum. The wavelength is characterized by a letter, which is added to the symbol  $n$  for the refractive index.

Note 2 to entry: Wavelengths to be used for the characterization of optical glasses, all kinds of optical systems and instruments, together with spectacle lenses, are specified in ISO 7944.

Note 3 to entry: The value of the refractive index can depend on the frequency, polarization, and the direction of light travel.

Note 4 to entry: The refractive index is expressed by  $n = c_0/c$ , where  $c_0$  is the velocity of light in vacuum and  $c$  is the velocity of light in the medium.

[SOURCE: CIE S 017:2011, 17-1074]

#### 3.4.2.1

##### absolute refractive index

$n_{\text{abs}}(\lambda)$

ratio of the velocity of an electromagnetic wave of a specific wavelength in vacuum to the velocity of its transmission through the optical glass, represented by  $n_{\text{abs}}(\lambda) = \frac{c}{v_\lambda}$ , where  $n_{\text{abs}}(\lambda)$  is absolute refractive index of arbitrary wavelength

$c$  is velocity of light in vacuum

$v_\lambda$  is velocity of light at arbitrary wavelength in optical glass

$\lambda$  is arbitrary wavelength of light

#### 3.4.2.2

##### relative refractive index

$n_{\text{rel}}(\lambda)$

ratio of (absolute) refractive index of the optical glass to the (absolute) refractive index of the medium in contact at a specific wavelength

#### 3.4.2.3

##### absolute temperature coefficient of refractive index

$\Delta n_{\text{abs}}/\Delta T$

ratio of refractive index change in vacuum to temperature change at a selected wavelength

Note 1 to entry: The absolute temperature coefficient of refractive index is expressed by the formula  $\Delta n_{\text{abs}}/\Delta T$  where  $\Delta n_{\text{abs}}$  is the change in refractive index for the change  $\Delta T$  in temperature.

Note 2 to entry: See also ISO 23584-2.

**3.4.2.4****relative temperature coefficient of refractive index**

$$\Delta n_{\text{rel}}/\Delta T$$

ratio of refractive index change at a given air pressure to temperature change at a selected wavelength

Note 1 to entry: The relative temperature coefficient of refractive index is expressed by the formula  $\Delta n_{\text{rel}}/\Delta T$  where  $\Delta n_{\text{rel}}$  is the change in refractive index for the change  $\Delta T$  in temperature.

Note 2 to entry: See also ISO 23584-2.

**3.4.2.5****principal refractive index**

refractive index either at the reference wavelength 546,07 nm (green mercury e-line) or at the reference wavelength 587,56 nm (yellow helium d-line)

Note 1 to entry: These principal refractive indices are denoted by  $n_e$  and  $n_d$  respectively.

**3.4.3****dispersion**

change of the refractive index with wavelength

[SOURCE: ISO 12123:2018, 3.4, modified — “measure of the” was removed.]

**3.4.3.1****principal dispersion**

difference of refractive indices at F-line and at C-line represented by  $n_F - n_C$ , where

$n_F$  is the refractive index at the F-line (486,13 nm)

$n_C$  is the refractive index at the C-line (656,27 nm)

or  $n_{F'} - n_{C'}$ , where

$n_{F'}$  is the refractive index of at the F'-line (479,99 nm)

$n_{C'}$  is the refractive index of at the C'-line (643,85 nm)

**3.4.3.2****Abbe number**

DEPRECATED: constringence

$v$

mathematical expression for determining the correction for chromatic aberration of optical glasses or components

EXAMPLE 1 The Abbe number for the d-line is defined as

$$v_d = \frac{n_d - 1}{n_F - n_C}$$

where

$n_d$  is the refractive index of the d-line (587,56 nm);

$n_F$  is the refractive index of the F-line (486,13 nm);

$n_C$  is the refractive index of the C-line (656,27 nm).

EXAMPLE 2 The Abbe number for the e-line is defined as

$$v_e = \frac{n_e - 1}{n_{F'} - n_{C'}}$$

where

$n_e$  is the refractive index of the e-line (546,07 nm);

$n_{F'}$  is the refractive index of the F'-line (479,99 nm);

$n_{C'}$  is the refractive index of the C'-line (643,85 nm).

Note 1 to entry: For wavelengths of the spectral lines, see ISO 7944.

### 3.4.3.3

#### partial dispersion

difference of refractive indices between two wavelengths  $\lambda_1$  and  $\lambda_2$  represented by  $n_{\lambda_1} - n_{\lambda_2}$

EXAMPLE  $n_F - n_C$ ;  $n_{F'} - n_{C'}$

$n_F$  and  $n_C$  are the refractive indices at wavelengths 486,13 nm and 656,27 nm, and  $n_{F'}$  and  $n_{C'}$  are the refractive indices at wavelengths 479,99 nm and 643,85 nm.  $n_F - n_C$  is frequently serving as reference and it is often called principal partial dispersion (defined in 3.4.3.1).

[SOURCE: ISO 12123:2018, 3.5]

#### 3.4.3.3.1

##### relative partial dispersion

difference of refractive indices,  $n_{\lambda_1} - n_{\lambda_2}$ , between two wavelengths  $\lambda_1$  and  $\lambda_2$  related to another partial dispersion,  $n_{\lambda_3} - n_{\lambda_4}$ , between two other wavelengths  $\lambda_3$  and  $\lambda_4$ , represented by  $P_{\lambda_1, \lambda_2, \lambda_3, \lambda_4} = (n_{\lambda_1} - n_{\lambda_2}) / (n_{\lambda_3} - n_{\lambda_4})$

EXAMPLE  $P_{g, F, F', C} = (n_g - n_F) / (n_{F'} - n_C) = P_{g, F}$

$n_g$  is the refractive index at wavelength 435,83 nm. If related to the principal partial dispersion,  $n_F - n_C$ , indices for  $\lambda_1$  and  $\lambda_2$  are usually omitted.

[SOURCE: ISO 12123:2018, 3.6]

#### 3.4.3.3.2

##### normal line

combination of partial dispersion/Abbe number of a standard crown and a standard flint glass type with the line parameters  $a_{\lambda_1, \lambda_2}$  and  $b_{\lambda_1, \lambda_2}$ , defined for each partial dispersion, represented by  $P_{\lambda_1, \lambda_2} = a_{\lambda_1, \lambda_2} + b_{\lambda_1, \lambda_2} \cdot v_d$

Note 1 to entry: See ISO 12123:2018.

#### 3.4.3.3.3

##### deviation of the relative partial dispersion

glass type specific distance of the relative partial dispersion  $P_{\lambda_1, \lambda_2}$  (glass type) from that of the normal line  $P_{\lambda_1, \lambda_2}$  (normal line), represented by either

$$\Delta P_{\lambda_1, \lambda_2} (\text{glass type}) = P_{\lambda_1, \lambda_2} (\text{glass type}) - P_{\lambda_1, \lambda_2} (\text{normal line}), \text{ or}$$

$$\Delta P_{\lambda_1, \lambda_2} (\text{glass type}) = P_{\lambda_1, \lambda_2} (\text{glass type}) - (a_{\lambda_1, \lambda_2} + b_{\lambda_1, \lambda_2} \cdot v_d),$$

here the line parameters  $a_{\lambda_1, \lambda_2}$  and  $b_{\lambda_1, \lambda_2}$  define the normal line  $\Delta P_{\lambda_1, \lambda_2}$  (normal line) =  $a_{\lambda_1, \lambda_2} + b_{\lambda_1, \lambda_2} \cdot V_d$  for each partial dispersion

Note 1 to entry: They are calculated from the partial dispersion/Abbe number combinations of a standard crown and a standard flint glass type.

Note 2 to entry: The deviation of the relative partial dispersion is a measure how suitable a glass type is for the correction of colour aberrations in imaging.

[SOURCE: ISO 12123:2018, 3.9]

#### 3.4.3.3.4

##### dispersion formula

formula for refractive index as function of wavelength

Note 1 to entry: The refractive index of an arbitrary wavelength can be calculated with the wavelength dispersion formula. The refractive index at an arbitrary wavelength can be calculated by using dispersion formula constants obtained by fitting the dispersion curve to the measured refractive index values.

#### 3.4.4

##### homogeneity

peak to valley of the refractive index variation within the predetermined area in a single glass sample

Note 1 to entry: The smaller the variation in the refractive index, the better the homogeneity.

[SOURCE: ISO 17411:2014, 3.1]

#### 3.4.5

##### absorbance

##### extinction

##### internal transmittance density

$E$

base 10 logarithm of the reciprocal of the transmitted light flux ratio to the incident light flux  $\tau_i$  on the

optical glass, represented by  $E = \log_{10} \frac{1}{\tau_i} = \alpha_1 d$ , where

$E$  is the absorbance

$\tau_i$  is the internal transmittance

$\alpha_1$  is the linear absorption coefficient

$d$  is the path length

Note 1 to entry: Absorbance includes not only attenuation of flux due to absorption but also attenuation due to reflection and scattering.

Note 2 to entry: Not to be confused with *optical density* (3.4.9), *transmittance density* (3.4.9).

#### 3.4.6

##### absorptance

$a$

ratio of the absorbed radiant flux to the incident flux

Note 1 to entry: In some cases the letter  $\alpha$  is used.

#### 3.4.6.1

##### **spectral absorptance**

$a(\lambda)$

ratio of the spectral radiant or luminous flux absorbed, to that of the incident radiant or luminous flux

[SOURCE: ISO 9211-1:2018, 3.1.2.3, modified — Note 1 to entry was removed and the symbol for absorptance  $\alpha$  was changed to  $a$ .]

#### 3.4.7

##### **absorption**

conversion of electromagnetic wave energy into another form of energy, for instance heat, by interaction with matter

[SOURCE: IEV 845-24-081]

#### 3.4.7.1

##### **selective absorption**

##### **selective transmittance**

attenuation of selective wavelengths (frequencies, “colours”) of light passing through a sample while other wavelengths pass unattenuated

#### 3.4.7.2

##### **coloration**

partial absorption in the visible spectrum by the creation of colour centres, e.g. introduction or absorbent ions or colloids

#### 3.4.8

##### **linear absorption coefficient**

quotient of the absorbance  $E$  by the path length  $d$  traversed by the radiation, represented by

$$\alpha_l = \frac{E}{d} = \frac{1}{d} \log_{10} \frac{1}{\tau_i}, \text{ where}$$

$\alpha_l$  is the linear absorption coefficient

$E$  is the absorbance

$d$  is the path length

$\tau_i$  is the internal transmittance

#### 3.4.9

##### **decadic absorbance**

##### **optical density**

##### **transmittance density**

##### **transmittance optical density**

$D_\tau$

logarithm to base 10 of the reciprocal of the transmittance, represented by  $D_\tau = \log_{10} \frac{1}{\tau} = \lg \frac{1}{\tau}$ , where

$D_\tau$  is the optical density;

$\tau$  is the transmittance

Note 1 to entry: Not to be confused with *absorbance* (3.4.5), *internal transmittance density* (3.4.5).

[SOURCE: IEV 845-24-072, modified — Omission of two Notes to entry.]

#### 3.4.10

##### **transmission**

passage of radiation through a medium without change in frequency of its monochromatic components

[SOURCE: IEV 845-24-048]

**3.4.11****transmittance**

ratio of the transmitted radiant flux to the incident radiant flux of a collimated, monochromatic beam that passes, at normal incidence, through a plane parallel polished plate

[SOURCE: ISO 12123:2018, 3.10]

**3.4.11.1****internal transmittance**

ratio of the transmitted radiant flux to the incident radiant flux of a collimated beam that passes, at normal incidence, through a plane parallel polished plate, excluding reflection losses at the surfaces

[SOURCE: ISO 12123:2018, 3.12]

**3.4.11.2****UV cut-off edge**

UVC 80/10

position and slope of the transmittance edge in the short wavelength side of visible light, given by the wavelengths at 80 % and 10 % internal transmittance

Note 1 to entry: Slope of the transmittance curve denotes the steepness of the UV cut-off (see ISO 12123:2018). The smaller the difference between  $\lambda_{80}$  and  $\lambda_{10}$ , the steeper the UV cut-off is.

**3.4.11.3****colour code**

CC

position of the transmittance edge in the short wavelength side of visible light, given by the wavelengths at 80 % and 5 % transmittance including reflection losses

Note 1 to entry: For glass types with refractive index  $n_d$  higher than 1,84, the reflection losses prevent transmission from exceeding 80 %. In this case the wavelength corresponding to 70 % is given instead (see ISO 12123:2018, 4.5.3).

[SOURCE: ISO 12123:2018, 3.15, modified — Added to the Note 1 to entry.]

**3.4.12****reflection**

process by which radiation is returned by a surface or a medium, without a change in the frequency of its monochromatic components

Note 1 to entry: Part of the radiation falling on a medium is reflected at the surface of the medium “surface reflection”; another part may be scattered back from the interior of the medium “volume reflection”.

Note 2 to entry: The frequency is unchanged only if there is no Doppler effect due to the motion of the optical glasses from which the radiation is returned.

[SOURCE: IEC 845-24-047]

**3.4.13****reflectance**

$\rho$

quotient of reflected radiant flux and incident radiant flux, represented by  $\rho = \frac{\Phi_r}{\Phi_m}$ , where

$\rho$  is the reflectance

$\Phi_r$  is the reflected radiant flux

$\Phi_m$  is the incident radiant flux

Note 1 to entry: Reflectance is also defined spectrally in terms of wavelength, in which case, “spectral” is added before the quantity name.

Note 2 to entry: Due to energy conservation,  $a + \rho + \tau = 1$  except when polarized radiation is observed, where  $a$  is absorptance and  $\tau$  is transmittance.

Note 3 to entry: Reflectance,  $\rho$ , is the sum of regular reflectance,  $\rho_r$ , and diffuse reflectance,  $\rho_d$ :  $\rho = \rho_r + \rho_d$ .

[SOURCE: IEV 845-24-064, modified — Omission of two Notes to entry and the symbol for absorptance  $\alpha$  was changed to  $a$ .]

#### 3.4.13.1

##### **regular reflectance specular reflectance**

ratio of the regularly reflected part of the (whole) reflected flux to the incident flux

[SOURCE: ISO 11382:2010, 3.2]

#### 3.4.13.2

##### **spectral reflectance**

$\rho(\lambda)$

ratio of the spectral radiant or luminous flux reflected to that of the incident radiant or luminous flux

#### 3.4.14

##### **spectral scattering**

change of the spatial distribution of a beam of radiation spread in many directions by a surface or a medium without any change of frequency of the monochromatic components of which the radiation is composed

#### 3.4.15

##### **luminescence**

emission, by atoms, molecules or ions in an optical glass, of optical radiation which for certain wavelengths or regions of the spectrum is in excess of the radiation due to thermal emission from that optical glass at the same temperature, as a result of these particles being excited by energy other than thermal agitation

Note 1 to entry: In the USA, this term sometimes applies to the emitted radiation.

[SOURCE: CIE S 017:2011, 17-722]

#### 3.4.16

##### **birefringence**

effect of an anisotropic medium characterized by the difference of the refractive indices of orthogonal polarizations

#### 3.4.17

##### **stress birefringence**

birefringence caused by mechanical stress within the optical glass

Note 1 to entry: Usually induced by either mechanical or thermal, or both stress; the refractive index depends on the orientation of the plane of polarization and the propagation vector of the electromagnetic wave with respect to the axis of the principal stresses.

Note 2 to entry: It is typically caused by residual stress in the glass blank after differential cooling during the forming and/or annealing process, or by certain manufacturing processes performed on the optics (see ISO 23584-2).

Note 3 to entry: For determination of birefringence, see ISO 11455.

#### 3.4.18

##### **fluorescence**

emission of optical radiation when a substance is exposed to any type of electromagnetic radiation, where the emitted radiation generally appears within 10 ns after the excitation

Note 1 to entry: Fluorescence is due to an “allowed” transition generally from an excited singlet state to a ground singlet state.



[SOURCE: CIE S 07:2011, 17-456, modified — Omission of one Note to entry.]

### 3.5 Non-optical properties

#### 3.5.1

##### coefficient of mean linear thermal expansion

DEPRECATED: expansion coefficient

$\alpha(T_0; T)$

ratio of the change in length of an optical glass specimen within a temperature interval divided by that temperature interval, related to initial specimen length, given by  $\alpha(T_0; T) = \frac{1}{l_0} \times \frac{l - l_0}{T - T_0}$ , where

$T_0$  is the initial or reference temperature

$T$  is the actual constant or variable temperature of specimen

$l_0$  is the length of specimen, usually a glass rod, under testing

$l$  is the length of specimen at temperature,  $T$

Note 1 to entry: For the determination of the coefficient of mean linear thermal expansion, see ISO 7991.

[SOURCE: ISO 7991:1987, Clause 3]

#### 3.5.2

##### Knoop hardness

$H_K$

number characterizing the resistance of a glass surface to permanent deformation

Note 1 to entry: Note to 1 entry: The Knoop hardness is determined according to ISO 9385.

#### 3.5.3

##### strain

$\varepsilon$

partial deformation of a body caused by the application of stress, either interior or exterior

Note 1 to entry: In the context of this document, it refers to the deformation of optical glass brought about by internal stresses set up through improper cooling or annealing during the glass manufacturing or working process.

#### 3.5.4

##### stress

$\sigma$

force per unit area applied to a body

Note 1 to entry: The following stresses should be distinguished:

- tensile stress;
- compressive stress;
- shear stress.

##### 3.5.4.1

##### internal stress

any condition of tensile, compressive or shear stresses existing within glass, particularly due to incomplete annealing, temperature gradient or inhomogeneity

**3.5.5**  
**stress optical coefficient**

*K*

ratio of stress birefringence effect to applied uniaxial stress on an optical glass

Note 1 to entry: For the determination of stress optical coefficient see ISO 10345-1 and ISO 10345-2.

**3.5.6**  
**chemical resistance**

resistance of glass to attack by neutral, alkaline or acid media

Note 1 to entry: The media can have a particular composition, e.g. detergents.

Note 2 to entry: For each attacking medium, special testing procedures are desirable and they are carried out by determining the loss in mass of the sample after attack, calculating the attacked depth, or by determining the changes of the surface by optical means.

Note 3 to entry: For the determination of water resistance, acid resistance, climate resistance, alkali resistance and phosphate resistance of raw optical glass, see ISO 21575, ISO 8424, ISO 22531, ISO 10629 and ISO 9689, respectively.

**3.5.7**  
**radiation resistance**

ability of a stabilized optical glass to retain its optical and other desired physical properties after exposure to high energy radiation

**3.5.8**  
**viscosity**

property characterized by resistance to flow under stress

Note 1 to entry: In the case of Newtonian behaviour, the rate of deformation is proportional to the stress.

Note 2 to entry: According to international convention, the preferred unit for the viscosity of glass is the SI sub-unit, decipascal second (dPa·s).

[SOURCE: ISO 7884-1:1987, 3.1]

**3.5.9**  
**Ranges of viscosity**

Note 1 to entry: With respect to practical application, the following three ranges of viscosity measurement are given in [3.5.9.1](#) to [3.5.9.3](#).

**3.5.9.1**  
**melting range**

range of viscosity up to  $10^3$  dPa·s

**3.5.9.2**  
**working range**

required viscosities in the range of  $10^3$  dPa·s to  $10^{7,6}$  dPa·s for typical hot-forming processing

**3.5.9.3**  
**annealing range**

temperature between the annealing point and the strain point

**3.5.10**  
**viscometric fixed point**

temperature  $\theta$  which characterizes the viscosity-temperature behaviour of a glass

Note 1 to entry: It is convenient to refer to the following temperatures as viscometric fixed points, see [3.5.10.1](#) to [3.5.10.4](#).

Note 2 to entry: For the determination of the viscosity and the viscometric fixed points, see ISO 7884.

### 3.5.10.1 working point

$\theta_{f1}$

viscometric fixed point, namely the temperature corresponding to a viscosity of  $\eta_{f1} = 10^4$  dPa·s

Note 1 to entry: The working point is determined by one of the methods described in ISO 7884-2 or ISO 7884-5.

### 3.5.10.2 softening point

$\theta_{f2}$

approximate temperature below which the glass behaves as a rigid solid in glass-forming operations and for a control test to indicate changes in composition

Note 1 to entry: The temperature is determined by the method described in ISO 7884-6. The corresponding viscosity is estimated by the following equation:

$$\eta_{f2} = 2,1 \times 10^7 \times \left( \rho - \frac{\sigma}{520} \right)$$

where

$\eta_{f2}$  softening point (dPa·s)

$\rho$  is the density of the glass ( $\text{g}\cdot\text{cm}^{-3}$ )

$\sigma$  is the surface tension ( $\text{mN}\cdot\text{m}^{-1}$ )

for  $\rho = 2,5 \text{ g}\cdot\text{cm}^{-3}$  and  $\sigma = 300 \text{ mN}\cdot\text{m}^{-1}$ , the viscosity is

$$\eta_{f2} = 10^{7,6} \text{ dPa}\cdot\text{s}$$

In most cases,  $\eta_{f2}$  lies close to that value; it shall be used if the value of  $\rho$  and  $\sigma$  are unknown. In extreme cases  $\eta_{f2}$  ranges from  $10^{7,5}$  dPa·s to  $10^8$  dPa·s.

Note 2 to entry: The softening point of a glass is defined in ASTM C338 as the temperature at which a round fibre, nominally 0,65 mm in diameter and 235 mm long, elongates under its own weight at a rate of 1 mm/min when the upper 100 mm of its length is heated at a rate of 5 °C/min.

Note 3 to entry: See ISO 7884-1:1987.

### 3.5.10.3 annealing point

$\theta_{f3}$

temperature at which the internal stress of the glass is substantially relaxed in a few minutes

Note 1 to entry: Annealing point corresponds to the upper temperature limit in the slow cooling zone and with a viscosity of the glass at this temperature of  $10^{13}$  dPa·s to  $10^{13,5}$  dPa·s.

Note 2 to entry: It is calculated by measuring the elongation speed of the glass fibre or the deflection speed of the glass beam.

[SOURCE: ISO 7884-7:1987, 4.2]

### 3.5.10.4 strain point

$\theta_{f4}$

temperature at which internal stresses in a glass are substantially relieved in a matter of hours

Note 1 to entry: This extrapolated deflection rate corresponds to a viscosity of approximately  $10^{14,7}$  dPa·s (see ISO 7884-7).

Note 2 to entry: The strain point is determined by extrapolation of the annealing point data and is the temperature at which the viscous deflection rate is 0,031 6 times that observed at the annealing point.

[SOURCE: ISO 7884-7:1987, 4.3]

### 3.5.10.5 transformation temperature

$T_g$   
temperature at which the glass changes from elastic to visco-elastic

Note 1 to entry: An abrupt change in the mechanical or thermal properties of the glass is observed around  $T_g$ .  $T_g$  is not a value inherent to the glass composition, but depends on the thermal history of the glass and the measurement method chosen. Thermal Mechanical Analysis (TMA), Differential Thermal Analysis (DTA) and Differential Scanning Calorimetry (DSC) are representative  $T_g$  measurement methods.

## 3.6 Imperfections

### 3.6.1 Glass imperfections

#### 3.6.1.1

##### striae

internal imperfections of a glass appearing as wavy distortions, usually representing a localized variation in refractive index

#### 3.6.1.2

##### bubble

gaseous inclusion in glass

Note 1 to entry: See also blister and seed.

#### 3.6.1.3

##### knot

nodular inclusion, often having an attenuated tail, which is to be regarded as a stone and which shows a much higher degree of attack by the glass melt

#### 3.6.1.4

##### inclusion

extraneous or foreign media (for instance bubble, seed, knot and stone) within the body of the glass

#### 3.6.1.5

##### stone

opaque residue of raw or refractory media not dissolved during the melting process

#### 3.6.1.6

##### seed

gaseous inclusion having a diameter smaller than 0,5 mm

Note 1 to entry: See also *blister* ([3.6.1.7](#)) and *bubble* ([3.6.1.2](#)).

#### 3.6.1.7

##### blister

elongated bubble, elliptical in shape and longer than 6 mm

Note 1 to entry: See also *bubble* ([3.6.1.2](#)).

### 3.6.2 Imperfections after optical processing

#### 3.6.2.1

##### scratch

score mark made by a hard body

**3.6.2.1.1****block rake**

chain-like scratch produced in polishing

**3.6.2.1.2****crush**

surface scratch or series of small scratches generally caused by mishandling

**3.6.2.1.3****runner-cut**

curved scratch caused by grinding

**3.6.2.1.4****sleek**

polishing (hairline) scratch without visible conchoidal fracturing of the edges

**3.6.2.2****pockmarks**

surface roughness in the form of very small digs

**3.6.2.3****dimming**

development and deposit of a corrosion substance during chemical attack on a glass surface, which gives a whitish cloudy colour to the surface layer

Note 1 to entry: Under a microscope, small white spots are visible. It appears most frequently when atmospheric attack (evaporation of water droplets, e.g. dew) has taken place.

Note 2 to entry: See also *haze* ([3.6.2.5](#)).

**3.6.2.4****grey**

incompletely polished surface showing a greyness resulting from the remains of fine grinding

**3.6.2.5****haze**

foggy appearance in a polished surface caused by light scattering

Note 1 to entry: The imperfections causing haze are larger than those causing fog, but not large enough to be resolved as individual particles by the unaided eye.

Note 2 to entry: See also *dimming* ([3.6.2.3](#)).

**3.6.2.6****lap**

fold in the surface of a glass

**3.6.2.7****line**

fine striation on the surface of glass

**3.6.2.8****orange peel**

numerous small regular imperfections giving the surface the appearance of an orange peel

**3.6.2.9****rib mark**

pattern of individual lines on a fractured surface or presenting an improperly polished surface which do not intersect and which also appear when a surface is polished without oscillation of the polishing lap

Note 1 to entry: In this case, the polished surface contains approximately parallel waves or ripples.

**3.6.2.10**

**staining**

development of interference colours on glass surfaces following chemical attack, which results from ion exchange (of soluble glass constituents from the glass surface against  $H^+$  of water) and the formation of a silica-rich layer

**3.6.2.11**

**wave**

local distortion of a surface detectable by deviation and usually due to improper polishing

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