



International  
Standard

**ISO 10678**

Second edition  
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**Fine ceramics (advanced ceramics,  
advanced technical ceramics) —  
Determination of photocatalytic  
activity of surfaces in an aqueous  
medium by degradation of  
methylene blue**

*Céramiques techniques — Détermination de l'activité  
photocatalytique des surfaces dans un milieu aqueux par  
dégradation du bleu de méthylène*

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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 document 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)).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at [www.iso.org/patents](http://www.iso.org/patents). ISO shall not be held responsible for identifying any or all such patent rights.

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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 206, *Fine ceramics*.

This second edition cancels and replaces the first edition (ISO 10678:2010), which has been technically revised.

The main changes are as follows:

- normative references have been updated;
- procedures for “Testing with intermittently stirred test cylinders” and “Testing with continuously stirred test cells” as “method A” and “method B” have been clarified and the whole document has been revised accordingly;
- precision data and interlaboratory test results for both methods have been updated and included in [Annex C](#);
- document has been editorially revised.

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).

# Fine ceramics (advanced ceramics, advanced technical ceramics) — Determination of photocatalytic activity of surfaces in an aqueous medium by degradation of methylene blue

## 1 Scope

This document specifies a method for the determination of the photocatalytic activity of surfaces by means of degradation of methylene blue (MB) in an aqueous medium under artificial irradiation, and characterises photocatalytically active surfaces with respect to their activity for degradation of dissolved organic molecules under radiant exposure to ultraviolet light.

This document does not apply for the characterization of surfaces with respect to their photocatalytic activity under visible light. A correlation of photocatalytic activity with the removal of direct soiling, the degradation of gaseous molecules in the environmental air or the antimicrobial efficacy can exist, especially for surfaces with low photonic efficiency.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 10677, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Ultraviolet light source for testing semiconducting photocatalytic materials*

## 3 Terms and definitions

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

ISO and IEC maintain terminology 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 specific photocatalytic activity

$P_{MB}$   
measure for the photochemical conversion

Note 1 to entry:  $P_{MB}$  is expressed in moles per square metre and hour [mol/(m<sup>2</sup>·h)].

### 3.2 photonic efficiency

$\zeta_{MB}$   
measure for the selectivity of the incident photons for methylene blue decolouration

Note 1 to entry: It is assumed that one photon is sufficient for the decolouration of a molecule.

Note 2 to entry:  $\zeta_{MB}$  is expressed as a percentage of the incident photons.

**3.3****testing solution**

aqueous solution of methylene blue, which serves as the reactive solution for the determination of the photocatalytic activity of surfaces

**3.4****measurement solution**

portion of the testing solution, the volume of which is < 10 % of the volume of the *testing solution* (3.3), used for the external determination of absorbance in a photometer

**3.5****conditioning solution**

aqueous methylene blue solution used for the pre-adsorption of methylene blue on the test surface prior to the determination of the optical absorbance employing a spectrometer

**4 Symbols and abbreviations**

For the purposes of this document, the symbols and units given in [Table 1](#) apply.

**Table 1 — Symbols and units**

| Designation                                                         | Symbol                                                                                           | Unit                    |
|---------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|-------------------------|
| Planck constant ( $h = 6,626 \cdot 10^{-34}$ Js)                    | $h$                                                                                              | Js                      |
| Speed of light ( $c = 3 \cdot 10^8$ m/s)                            | $c$                                                                                              | m/s                     |
| Avogadro constant ( $N_A = 6,022 \cdot 10^{23}$ mol <sup>-1</sup> ) | $N_A$                                                                                            | mol <sup>-1</sup>       |
| Relative molecular mass                                             | $M$                                                                                              | g/mol                   |
| Molar extinction coefficient                                        | $\varepsilon$                                                                                    | m <sup>2</sup> /mol     |
| Time                                                                | $t$                                                                                              | h                       |
| Measuring time                                                      | $t_m$                                                                                            | h                       |
| Concentration of methylene blue                                     | $c_{MB}$                                                                                         | mol/l                   |
| Initial concentration of methylene blue in the testing solution     | $c_{MB0}$                                                                                        | mol/l                   |
| Absorbance                                                          | $A_\lambda$                                                                                      | 1                       |
| Gauge length                                                        | $d$                                                                                              | mm                      |
| Volume                                                              | $V$                                                                                              | l                       |
| Internal diameter                                                   | $d_i$                                                                                            | mm                      |
| Irradiated surface                                                  | $A$                                                                                              | m <sup>2</sup>          |
| Wavelength                                                          | $\lambda$                                                                                        | m                       |
| Irradiance                                                          | $E$                                                                                              | W/m <sup>2</sup>        |
| Average irradiance                                                  | $E_{av} = \frac{\int E dt}{t_m}$                                                                 | W/m <sup>2</sup>        |
| Specific degradation rate                                           | $R = \frac{\Delta A_\lambda \cdot V}{\Delta t \cdot \varepsilon \cdot d \cdot A}$                | mol/(m <sup>2</sup> ·h) |
| Specific degradation rate under radiant exposure                    | $R_{irr} = \frac{\Delta A_{\lambda, irr} \cdot V}{\Delta t \cdot \varepsilon \cdot d \cdot A}$   | mol/(m <sup>2</sup> ·h) |
| Specific degradation rate without radiant exposure                  | $R_{dark} = \frac{\Delta A_{\lambda, dark} \cdot V}{\Delta t \cdot \varepsilon \cdot d \cdot A}$ | mol/(m <sup>2</sup> ·h) |
| Specific photocatalytic activity                                    | $P_{MB} = R_{irr} - R_{dark}$                                                                    | mol/(m <sup>2</sup> ·h) |

Table 1 (continued)

| Designation               | Symbol                                                                 | Unit                    |
|---------------------------|------------------------------------------------------------------------|-------------------------|
| Photon irradiance         | $E_p = \frac{\lambda_{\max} \cdot E_{av}}{h \cdot c \cdot N_A} 3\,600$ | mol/(m <sup>2</sup> ·h) |
| Average photon irradiance | $E_{p,av}$                                                             | mol/(m <sup>2</sup> ·h) |
| Photonic efficiency       | $\zeta_{MB} = \frac{P_{MB}}{E_p} \times 100$                           | %                       |

## 5 Principle

In an aqueous solution, methylene blue is brought into contact with the photocatalytically active surface of a test specimen; this surface is irradiated through the supernatant solution with photolytically non-active radiation ( $320 \text{ nm} \leq \lambda \leq 400 \text{ nm}$ ). The solution will decolour. The dye content in the solution is determined at regular intervals (method A) or continuously (method B) during measurement using UV/visible spectroscopy. For the determination of the apparent photocatalytic decolourisation due to e.g. adsorption, a reference measurement is either made by using a photocatalytically active coating of a test specimen without radiant exposure or by measuring an equivalent test specimen in parallel in a second vessel whose surface is shaded against radiation (darkness specimen). The specific degradation rate and the photonic efficiency of the test specimen's surface are calculated from the measurements.

## 6 Apparatus

### 6.1 General

In addition to standard laboratory equipment, the following equipment according to 6.2 to 6.8 shall be used. All equipment that comes into contact with the methylene blue solutions shall be made of materials which only show a low adsorption of methylene blue, e.g. glass, stainless steel, polyethylene, polypropylene, polyacrylate or certain polysiloxanes with low organic emissions. Care shall be taken to ensure that the amount of scattered light in the test setup is as low as possible.

### 6.2 Measuring device

The measuring device either consists of two test cylinders that are glued to the test specimen, or of two test cells, each consisting of a vessel into which a specimen holder is embedded (see Annex B for a schematic representation of the measuring device).

### 6.3 Glass pane

For covering the test cylinders or the test cells in order to prevent evaporation, with low absorption within the spectral region of the light source (6.4).

### 6.4 Light source

Narrow-band radiator with emissions only in the range of  $320 \text{ nm} \leq \lambda \leq 400 \text{ nm}$  (ultraviolet A spectrum) with an irradiance of  $E = (10 \pm 0,5) \text{ W/m}^2$ , measured at the height of the specimen underneath the glass pane cover.

NOTE 1 A suitable selection of light sources is given in ISO 10677.

NOTE 2 UV-LED light sources can be used to irradiate the test specimens, provided that their application complies with the specifications for testing semiconducting photocatalytic materials[1].

### 6.5 UV radiometer

Device for measuring the UV irradiance, calibrated to the characteristics of the light source and in accordance with ISO 10677.

## 6.6 Photometer or UV/visible spectrometer

Device for the determination of the methylene blue concentration, calibrated in the measurement range of  $600 \text{ nm} \leq \lambda \leq 700 \text{ nm}$  in accordance with the instrument manual.

## 6.7 Measuring cuvette

Cuvette made of glass or plastic with an optical path length of 10 mm and a transmission of  $> 80 \%$  in the wavelength range of  $600 \text{ nm} \leq \lambda \leq 700 \text{ nm}$ , used in a spectrometer for the external determination of the methylene blue concentration.

## 6.8 Magnetic stirrer

Electric device with a cylindrical magnetic stir bar ( $20 \text{ mm} \times 3 \text{ mm}$ ), used for stirring the methylene blue solution according to method B (11.3).

## 7 Calibration

The equipment according to 6.5, 6.6 and 6.7 as well as the balances used shall be calibrated in accordance with the equipment manual.

## 8 Testing and conditioning solutions

For the purposes of testing and conditioning, methylene blue solutions shall be used. On the basis of distilled water (conductivity  $< 5 \mu\text{S}/\text{cm}^2$ ), the initial methylene blue concentration in the testing solution shall be  $c_{\text{MB0}} = (10 \pm 0,5) \mu\text{mol}/\text{l}$ . The conditioning solution shall be prepared with a concentration of  $c_{\text{MB}} = (20 \pm 1,0) \mu\text{mol}/\text{l}$ . The absorbance  $A_\lambda$  of the solutions shall be calculated according to Formula (1) and is  $A_{\lambda, \text{max}} = 0,74$  for the testing solution or  $A_{\lambda, \text{max}} = 1,48$  for the conditioning solution at a gauge length  $d = 10 \text{ mm}$ .

$$A_\lambda = \epsilon \cdot c_{\text{MB}} \cdot d \quad (1)$$

NOTE Methylene blue ( $\text{C}_{16}\text{H}_{18}\text{ClN}_3\text{S} \cdot 3\text{H}_2\text{O}$ ; molar mass  $M = 373,90 \text{ g/mol}$ ; CAS-No. 7220-79-3) is a low-absorptive dye when it is used in the wavelength range of  $350 \text{ nm} \leq \lambda \leq 450 \text{ nm}$ . At a concentration of  $c_{\text{MB}} = 10 \mu\text{mol}/\text{l}$  in an aqueous solution ( $\text{pH} = 5,5$ ), methylene blue shows a molar extinction coefficient of  $\epsilon_{\lambda, \text{max}=664 \text{ nm}} = 7\,402,8 \text{ m}^2/\text{mol}$  (see [2]).

## 9 Preparation of the test specimens

The test specimens shall have a geometrical surface of  $(1\,250 \pm 50) \text{ mm}^2$  to  $(10\,000 \pm 100) \text{ mm}^2$ . For tests according to method B (see 11.3), a specimen size of  $(49,5 \pm 0,5) \text{ mm} \times (24,5 \pm 0,5) \text{ mm}$  is defined. Prior to the measurement all specimens shall be cleaned according to the manufacturer's instructions. In case no manufacturer's instructions are available, the specimens should be used at the earliest 12 h after its preparation and stored under free air circulation at  $(23 \pm 5) ^\circ\text{C}$  and  $(50 \pm 10) \%$  relative humidity at least 1 h before starting the final cleaning step. For more detailed information on storage and preconditioning of specimens see [3]. For strongly absorbing specimens, the lateral surfaces shall be covered with an inert material, e.g. hard lacquer or aluminum tape. In the last cleaning step, the specimens shall be kept under ultraviolet radiation with a wavelength  $\lambda < 400 \text{ nm}$  and an irradiance  $E > 10 \text{ W}/\text{m}^2$  for 24 h to 72 h.

For the purposes of conditioning, two equal specimens (test specimen and darkness reference specimen) shall each be placed in a vessel containing the conditioning solution (see Clause 8). Either the conditioning solution shall be poured into the cylinders in case the test cylinders are glued ( $V = (35 \pm 0,5) \text{ ml}$ ), or the test specimens shall be placed directly into the conditioning solution ( $V = (90 \pm 0,5) \text{ ml}$ ). Both vessels containing the test specimens and the conditioning solution shall be stored in the dark for an equal duration of at least 12 h. Once the concentration of the conditioning solution is below that of the testing solution, the test specimen is not suitable for measurements according to this document and the result shall be recorded in the test report.

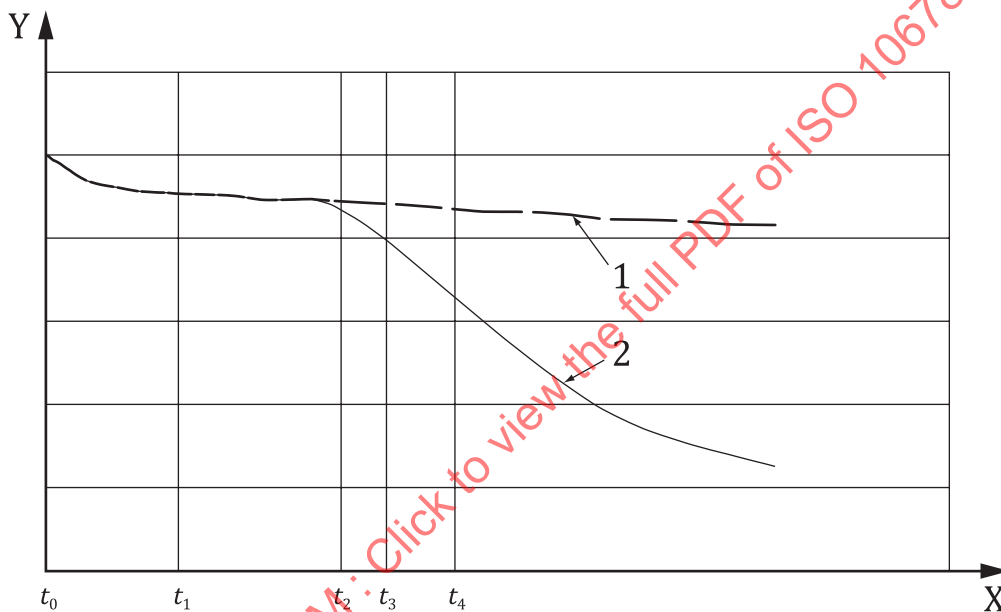
## 10 Preparation of the measurement

In case of test cylinders that are glued (method A; see B.1), the conditioning solutions shall be exchanged for the testing solutions at the time  $t_0$  (see Figure 1). Cylinders with an internal diameter  $d_i = (41 \pm 1)$  mm and a length of  $(35 \pm 5)$  mm shall be used as test cylinders. The volume of the testing solution is  $V = (35 \pm 0,5)$  ml, which shall be determined exactly.

NOTE Commercially available ISO-KF DN40 flanges according to ISO 2861<sup>[4]</sup> with pipe extension of steel or borosilicate glass can be used as test cylinders.

When using test cells (method B; see B.2), the two conditioned test specimens shall be inserted into the measuring device (6.2) with the testing solutions and be stored in the dark until time  $t_0$  (see Figure 1). Commercially available large cuvettes with a gauge length of  $d = (50 \pm 0,5)$  mm and a nominal volume of  $V = (90 \pm 0,5)$  ml shall be used as test cells.

Test cylinders, test cells and measuring cuvettes shall be cleaned with a commercially available cuvette cleaner to remove any adhering methylene blue residues prior to use.



### Key

|   |                                                                                      |       |                                      |
|---|--------------------------------------------------------------------------------------|-------|--------------------------------------|
| X | time                                                                                 | $t_0$ | start of measurement                 |
| Y | absorbance, $A_\lambda$                                                              | $t_1$ | start of linear range                |
| 1 | absorbance-time curve of the testing solution in the dark (without radiant exposure) | $t_2$ | start of UV irradiation              |
|   |                                                                                      | $t_3$ | start of measurement time; $t_m = 0$ |
| 2 | absorbance-time curve of the testing solution under radiant exposure                 | $t_4$ | end of linear range                  |

**Figure 1 — Schematic representation of the course of the absorbance-time curves in the dark and under radiant exposure**

## 11 Measurement procedure

### 11.1 General

The test cells or test cylinders shall be covered with the glass pane (6.3). The vessel containing the darkness specimen shall be additionally shielded from UV radiation. Irradiation of the specimen is started as soon as the absorbance-time curve of the testing solution (see curves 1 and 2 in Figure 1) is nearly constant, i.e. in the range from  $t_1$  to  $t_2$ . The light source (6.4) shall ensure an irradiance  $E = (10 \pm 0,5)$  W/m<sup>2</sup>, measured

underneath the glass pane at the height of the test specimen. The test temperature of the testing solution shall be  $(22 \pm 3) ^\circ\text{C}$  and shall be recorded. Measurement and verification of the temperature is permitted inside as well as near the test cylinders or test cells. The absorbance shall be measured at a wavelength of  $\lambda = (664 \pm 5) \text{ nm}$ .

## 11.2 Testing with intermittently stirred test cylinders (method A)

The methylene blue testing solution shall be homogenised during the test by brief stirring (for about 3 s) every 20 min using a glass bar or stirrer. The absorbance shall be determined during the irradiation process by external measurements of the measurement solutions (3.4) extracted from the testing solution (3.3), and subsequent recirculation of the measurement solution into the testing solution. The absorbance shall be measured at intervals of 20 min each, where the measurement solution shall always be extracted immediately after stirring. The measurement under radiant exposure shall be carried out over a period of 3 h, but at most until the solution has decoloured.

If the evaluation of results (see Clause 12) shows a high average photonic efficiency of  $\eta_{\text{MB}} > 0,10 \%$ , the measurement shall be repeated with an irradiance of  $E = (2,5 \pm 0,13) \text{ W/m}^2$ . If the subsequent data analysis results in a higher value for the photonic efficiency than that obtained at a higher irradiance, the value that has been determined at an irradiance of  $E = (2,5 \pm 0,13) \text{ W/m}^2$  shall be stated in the test report. The observation of a high average photonic efficiency at an irradiance of  $E = (10 \pm 0,5) \text{ W/m}^2$  shall be stated in the test report.

## 11.3 Testing with continuously stirred test cells (method B)

In order to be able to obtain an evenly mixed testing solution, the test cells are placed on a magnetic stirrer. For the tests applied with continuous stirring, the test specimens shall be supported on specimen holders at a distance of  $(10 \pm 0,5) \text{ mm}$  above the vessel bottom of the test cells (see B.2). Therefore, a distance of at least 5 mm from the edge of the test cells must be ensured on at least two sides of the specimen holder to enable uniform mixing. Stirring is carried out using a cylindrical magnetic stir bar ( $20 \text{ mm} \times 3 \text{ mm}$ ) with a stirring speed of  $(400 \pm 20) \text{ min}^{-1}$ . For the direct measurement of the testing solution inside the test cell, the absorption-concentration curve of the methylene blue solution shall first be determined by means of a calibration measurement within the concentration range of  $7,5 \mu\text{mol/l} \leq c_{\text{MB}} \leq 10,5 \mu\text{mol/l}$ . The measurement under radiant exposure shall be carried out over a period of 3 h, but at most until the calibrated measurement range is undercut.

Equivalent to both procedures, a curve without radiant exposure (darkness specimen) shall be measured under otherwise identical conditions (see curve 1 in Figure 1).

# 12 Evaluation of results

## 12.1 General

For the evaluation of measurement results, only values in the linear range corresponding to those from  $t_3$  to  $t_4$  in Figure 1 may be used. The linear range should therefore extent over at least 5 measured values at intervals of 20 min, where a maximum of one value is permitted to be an outlier which shall be justified in the test report. Deviations from linearity shall be stated in the test report (Clause 14). The absorbance values shall be rounded to three decimal places and summarised in a time/absorbance table (see Table A.1). A determination of the measured values via linear regression is permitted (see evaluation example in A.2).

An example of evaluation is given in Annex A.

## 12.2 Specific degradation rate $R$

The specific degradation rate  $R$ , in  $\text{mol}/(\text{m}^2 \cdot \text{h})$ , shall be calculated according to Formula (2):

$$R = \frac{\Delta A_\lambda \cdot V}{\Delta t \cdot \varepsilon \cdot d \cdot A} \quad (2)$$

### 12.3 Photon irradiance $E_p$

The photon irradiance  $E_p$ , in mol/(m<sup>2</sup>·h), shall be calculated from the constant irradiance  $E$  according to [Formula \(3\)](#):

$$E_p = \frac{\lambda_{\max} \cdot E}{h \cdot c \cdot N_A} 3600 = \lambda_{\max} \cdot E \cdot 30074 \quad (3)$$

### 12.4 Average irradiance $E_{av}$

The average irradiance  $E_{av}$ , in W/m<sup>2</sup>, shall be calculated according to [Formula \(4\)](#):

$$E_{av} = \frac{\int E dt}{t_m} \quad (4)$$

### 12.5 Average photon irradiance $E_{p,av}$

The average photon irradiance  $E_{p,av}$ , in mol/(m<sup>2</sup>·h), shall be calculated from the average irradiance  $E_{av}$  according to [Formula \(5\)](#):

$$E_{p,av} = \frac{\lambda_{\max} \cdot E_{av}}{h \cdot c \cdot N_A} 3600 = \lambda_{\max} \cdot E_{av} \cdot 30074 \quad (5)$$

### 12.6 Specific photocatalytic activity $P_{MB}$

The specific photocatalytic activity  $P_{MB}$ , in mol/(m<sup>2</sup>·h), shall be calculated according to [Formula \(6\)](#):

$$P_{MB} = R_{irr} - R_{dark} \quad (6)$$

### 12.7 Photonic efficiency $\zeta_{MB}$

The photonic efficiency  $\zeta_{MB}$ , in %, shall be calculated according to [Formula \(7\)](#):

$$\zeta_{MB} = \frac{P_{MB}}{E_p} \cdot 100 \quad (7)$$

## 13 Precision

### 13.1 Repeatability

The absolute difference between two independent single test results obtained using the same method on identical test material in the same laboratory by the same operator using the same equipment within a short interval of time will not exceed the repeatability limit,  $r$ , in more than 5 % of cases. Typical precision data obtained in an interlaboratory test are given in [Annex C](#).

### 13.2 Reproducibility

The absolute difference between two independent single test results obtained using the same method on identical test material in different laboratories by different operators using different equipment will not exceed the reproducibility limit,  $R$ , in more than 5 % of cases. Typical precision data obtained in an interlaboratory test are given in [Annex C](#).

## 14 Test report

The test report shall include at least the following information:

- a) a reference to this document, i.e. ISO 10678:2024;
- b) name of the laboratory;
- c) date of the test;
- d) information on the test piece (dimensions, appearance, pre-treatment of the surface to be tested);
- e) information on the measurement method (method A or method B);
- f) temperature inside the laboratory and of the measurement solution;
- g) light source used;
- h) manufacturer and radio-photometer or UV/visible spectrometer type;
- i) irradiance  $E$  (measured at the height of the specimen surface underneath the glass cover);
- j) specific photocatalytic activity  $P_{MB}$ , information on constancy (standard deviation  $s$  across 5 measurement values; if determined by linear regression, specification of the standard deviation of the slope) and outliers;
- k) photonic efficiency  $\zeta_{MB}$ , information on constancy;
- l) graphic representation of evaluation;
- m) any unusual features that were detected during the determination and that could affect the result;
- n) any deviations from this document or procedures that were considered to be optimal.

## Annex A (informative)

### Example of an evaluation

#### A.1 Evaluation example for measurements including test cylinders

This evaluation example assumes a test volume of  $V = 0,035$  l for glued test cylinders with an internal diameter of  $d_i = 40$  mm, a surface area of  $A = 12,56$  cm<sup>2</sup>, an irradiance wavelength of  $\lambda = 365$  nm and a gauge length of  $d = 10$  mm.

Set the measurement time at which the evaluation will start to  $t_m = 0$  min (this equals  $t_3$  in Figure 1). The evaluation range ends at the end of the linear range at  $t_m = 120$  min ( $t_4$  in Figure 1). Calculate the specific degradation rates  $R_{irr}$  and  $R_{dark}$ , the specific photocatalytic activity  $P_{MB}$  and the photonic efficiency  $\zeta_{MB}$  according to Formula (2) to Formula (7). Determine the values by taking the difference of successive values at  $t_m$  and  $A_\lambda$ . From the time  $t_m > 120$  min the values of the specific photocatalytic activity and the photonic efficiency will start to decrease constantly. Consequently, the values at  $t_m > 120$  min will be neglected. As a result, determine the arithmetic mean of the values for  $P_{MB}$  and  $\zeta_{MB}$  obtained within the time  $t_m$  between 40 min and 120 min. In this example, the specific degradation rate is  $P_{MB} = (4,10 \pm 0,4) \cdot 10^{-5}$  mol/(m<sup>2</sup>·h) and the photonic efficiency is  $\zeta_{MB} = 0,037$  %. The results obtained in this example are given in Table A.1.

Table A.1 — Evaluation of exemplary measurement results

| $t_m$<br>min | $t_m$<br>h | $A_{\lambda,irr}$<br>1 | $A_{\lambda,dark}$<br>1 | $E, E_{av}$<br>W/m <sup>2</sup> | $E_p, E_{p,av}$<br>mol/(m <sup>2</sup> ·h) | $R_{irr}$<br>mol/(m <sup>2</sup> ·h) | $R_{dark}$<br>mol/(m <sup>2</sup> ·h) | $P_{MB}$<br>mol/(m <sup>2</sup> ·h) | $\zeta_{MB}$<br>% |
|--------------|------------|------------------------|-------------------------|---------------------------------|--------------------------------------------|--------------------------------------|---------------------------------------|-------------------------------------|-------------------|
| 0            | 0,00       | 0,733                  | 0,704                   | 10                              | 0,110                                      | —                                    | —                                     | —                                   | —                 |
| 20           | 0,33       | 0,713                  | 0,708                   | 10                              | 0,110                                      | 2,12E-05                             | -3,92E-06                             | 2,51E-05                            | 0,023             |
| 40           | 0,67       | 0,666                  | 0,703                   | 10                              | 0,110                                      | 4,94E-05                             | 4,70E-06                              | 4,47E-05                            | 0,041             |
| 60           | 1,00       | 0,626                  | 0,700                   | 10                              | 0,110                                      | 4,31E-05                             | 3,14E-06                              | 4,00E-05                            | 0,036             |
| 80           | 1,33       | 0,583                  | 0,697                   | 10                              | 0,110                                      | 4,47E-05                             | 3,92E-06                              | 4,08E-05                            | 0,037             |
| 100          | 1,67       | 0,543                  | 0,699                   | 10                              | 0,110                                      | 4,23E-05                             | -2,35E-06                             | 4,47E-05                            | 0,041             |
| 120          | 2,00       | 0,509                  | 0,697                   | 10                              | 0,110                                      | 3,68E-05                             | 1,57E-06                              | 3,53E-05                            | 0,032             |
| 140          | 2,33       | 0,476                  | 0,694                   | 10                              | 0,110                                      | 3,45E-05                             | 3,14E-06                              | 3,14E-05                            | 0,029             |
| 160          | 2,67       | 0,443                  | 0,695                   | 10                              | 0,110                                      | 3,53E-05                             | -7,84E-07                             | 3,61E-05                            | 0,033             |
| 180          | 3,00       | 0,415                  | 0,693                   | 10                              | 0,110                                      | 2,98E-05                             | 2,35E-06                              | 2,74E-05                            | 0,025             |

#### A.2 Evaluation example for measurements including test cells

This evaluation example assumes two test cells arranged in parallel with a test volume of  $V = 0,090$  l, a surface area of  $A = 12,5$  cm<sup>2</sup> and an irradiance wavelength of  $\lambda = 365$  nm. Assume a gauge length for the measurement cuvette of  $d = 10$  mm. The absorption-concentration curves of the methylene blue solutions have been determined earlier in the concentration range of  $7,5 \mu\text{mol/l} \leq c_{MB} \leq 10,5 \mu\text{mol/l}$  by means of calibration measurement using linear regression with  $A_1 = 6,084 - 0,364 c_{MB}$  for the first and  $A_2 = 6,051 - 0,360 c_{MB}$  for the second test cell.

Set the measurement time at which the evaluation will start to  $t_m = 0$  min (this equals  $t_3$  in Figure A.1). The evaluation range ends at the end of the linear range at  $t_m = 80$  min ( $t_4$  in Figure A.1). Calculate the absorption values using linear regression with  $A_{irr} = 0,828 - (1,55 \pm 0,01) \cdot 10^{-3}t$  and  $A_{dark} = 0,742 - (4,02 \pm 0,03) \cdot 10^{-5}t$ . Calculate the specific degradation rates  $R_{irr}$  and  $R_{dark}$ , the specific photocatalytic activity  $P_{MB}$  and the photonic efficiency  $\zeta_{MB}$  according to Formula (2) to Formula (7). Determine the values by taking the difference of the values  $t_m$  and  $A_\lambda$  obtained at the time  $t_m = 0$  min and  $t_m = 80$  min. In this example, the

specific degradation rate is  $P_{MB} = (4,22 \pm 0,01) \cdot 10^{-5} \text{ mol}/(\text{m}^2 \cdot \text{h})$  and the photonic efficiency is  $\zeta_{MB} = 0,038 \%$ . The results obtained in this example are given in [Table A.2](#).

Table A.2 — Evaluation of exemplary measurement results

| $t_m$<br>min | $t_m$<br>h | $A_{\lambda, \text{irr}}$<br>1 | $A_{\lambda, \text{dark}}$<br>1 | $E, E_{\text{av}}$<br>W/m <sup>2</sup> | $E_p, E_{p, \text{av}}$<br>mol/(m <sup>2</sup> ·h) | $R_{\text{irr}}$<br>mol/(m <sup>2</sup> ·h) | $R_{\text{dark}}$<br>mol/(m <sup>2</sup> ·h) | $P_{MB}$<br>mol/(m <sup>2</sup> ·h) | $\zeta_{MB}$<br>% |
|--------------|------------|--------------------------------|---------------------------------|----------------------------------------|----------------------------------------------------|---------------------------------------------|----------------------------------------------|-------------------------------------|-------------------|
| 0            | 0,00       | 0,704                          | 0,739                           | 10                                     | 0,110                                              | —                                           | —                                            | —                                   | —                 |
| 80           | 1,33       | 0,580                          | 0,736                           | 10                                     | 0,110                                              | 4,32E-05                                    | 1,05E-06                                     | 4,22E-05                            | 0,038             |

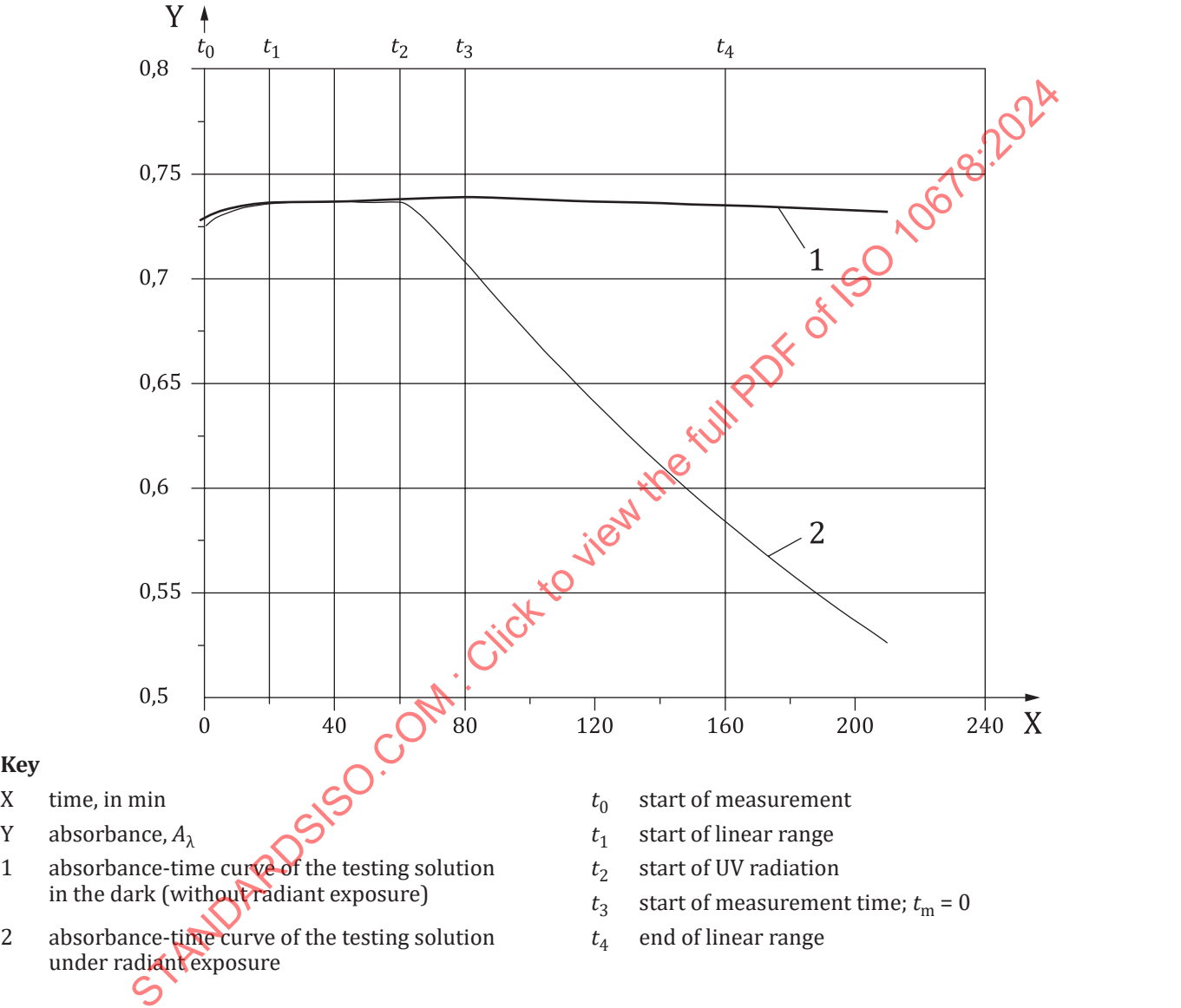


Figure A.1 — Schematic representation of the course of the absorbance-time curves in the dark and under radiant exposure

## Annex B (informative)

### Examples of measuring devices

#### B.1 Assembly of the measuring device including test cylinders

[Figure B.1](#) shows the schematic assembly of a measuring device including test cylinders.

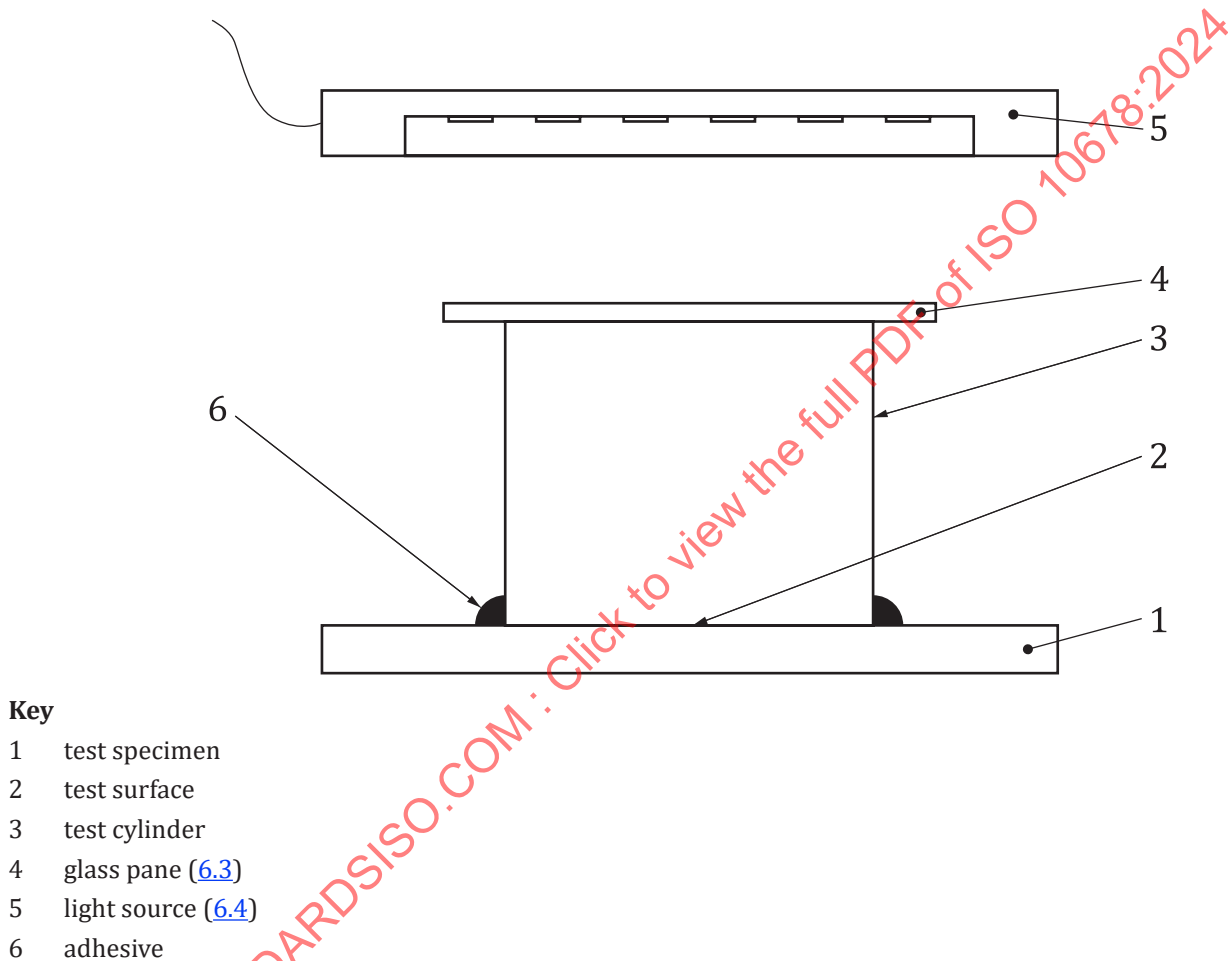
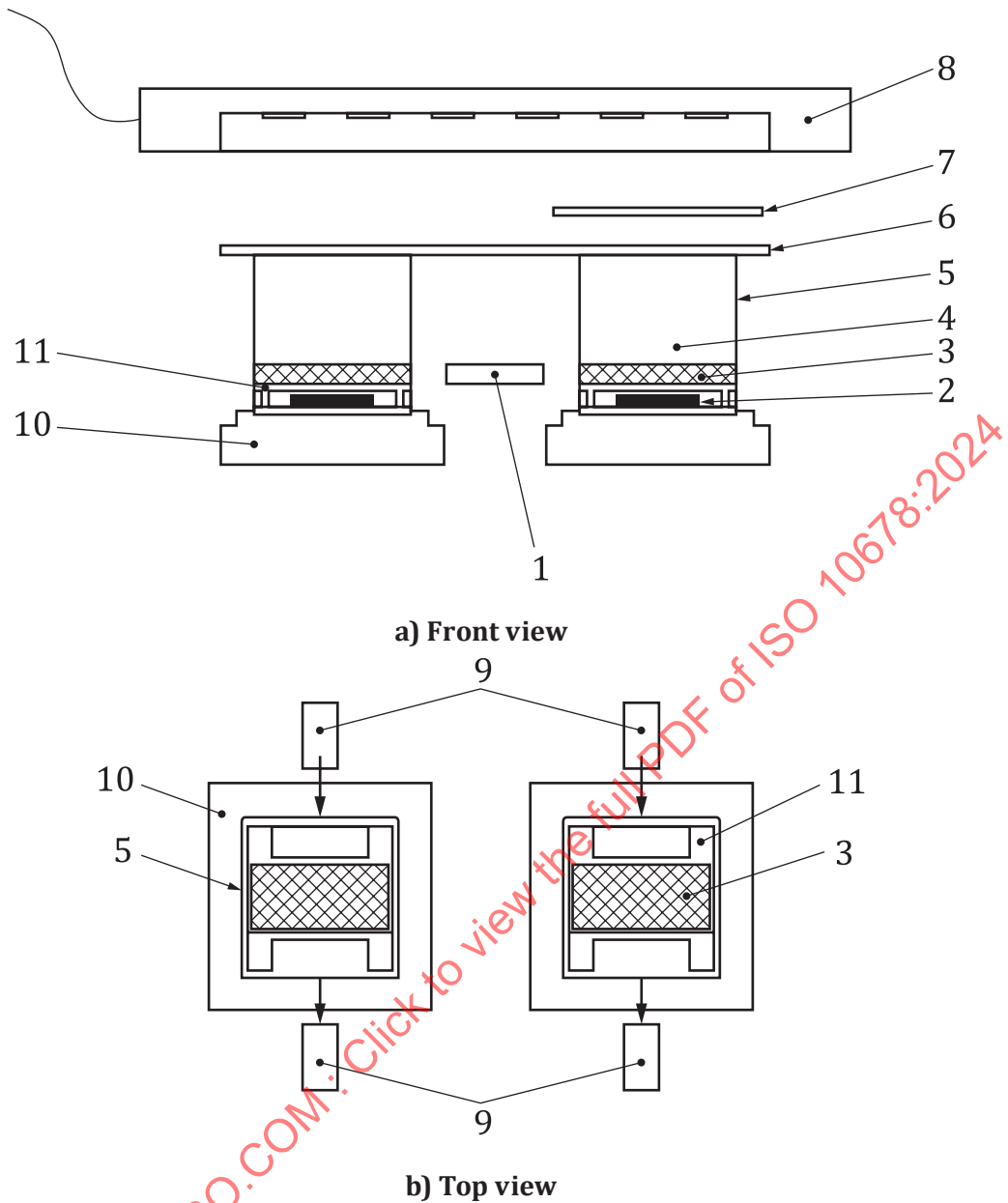


**Figure B.1 — Schematic assembly of a measuring device including test cylinders**

#### B.2 Assembly of the measuring device including test cells

[Figure B.2](#) shows the schematic assembly of a measuring device including test cells.



**Key**

- |   |                       |    |                                                 |
|---|-----------------------|----|-------------------------------------------------|
| 1 | UV radiometer (6.5)   | 7  | wide-area cover for shielding from UV radiation |
| 2 | magnetic stirrer core | 8  | light source (6.4)                              |
| 3 | test specimen         | 9  | photometer or UV/visible spectrometer (6.6)     |
| 4 | testing solution      | 10 | magnetic stirrer (6.8)                          |
| 5 | test cells            | 11 | specimen holder                                 |
| 6 | glass pane (6.3)      |    |                                                 |

**Figure B.2 — Schematic assembly of a measuring device including test cells**