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Standard Terminology Relating to Radiation Measurements and Dosimetry[1]

This standard is issued under the fixed designation E170; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This terminology generally covers terms that apply to radiation measurements and dosimetry associated with energy deposition and radiation effects, or damage, in materials caused by interactions by high-energy radiation fields. The common radiation fields considered are X-rays, gamma rays, electrons, alpha particles, neutrons, and mixtures of these fields. This treatment is not intended to be exhaustive but reflects special and common terms used in technology and applications of interest to Committee E10, as for example, in areas of radiation effects on components of nuclear power reactors, radiation hardness testing of electronics, and radiation processing of materials.

This terminology uses recommended definitions and concepts of quantities, with units, for radiation measurements as contained in the International Commission on Radiation Units and Measurements (ICRU) Report 85a on "Fundamental Quantities and Units for Ionizing Radiation," October 2011.[2] Those terms that are defined essentially according to the terminology of ICRU Report 85a will be followed by ICRU in parentheses. It should also be noted that the units for quantities used are the latest adopted according to the International System of Units (SI) which are contained in Appendix X1 as taken from a table in ICRU Report 85a.[2] This terminology also uses recommended definitions of two JCGM documents,[3] namely "International vocabulary of metrology" (VIM, 2012, unless indicated otherwise) and "Guide to the expression of uncertainty in measurement" (GUM, 2008). Those terms that are defined essentially according to the terminology of these documents will be followed by either VIM or GUM in parentheses.

A term is boldfaced when it is defined in this standard. For some terms, text in italics is used just before the definition to limit its field of application, for example, see **activity**.

1. Referenced Documents

1.1 *ASTM Standards:*[4]

E380 Practice for Use of the International System of Units (SI) (the Modernized Metric System) (Withdrawn 1997)[5]

E722 Practice for Characterizing Neutron Fluence Spectra in Terms of an Equivalent Monoenergetic Neutron Fluence for Radiation-Hardness Testing of Electronics

E910 Test Method for Application and Analysis of Helium Accumulation Fluence Monitors for Reactor Vessel Surveillance

1.2 *Joint Committee for Guides in Metrology (JCGM) Reports:*[3]

JCGM 100:2008, GUM 1995 with minor corrections, Evaluation of measurement data – Guide to the expression of uncertainty in measurement

JCGM 200:2012, VIM International vocabulary of metrology – Basic and general concepts and associated terms

[1] This terminology is under the jurisdiction of ASTM Committee E10 on Nuclear Technology and Applications and is the direct responsibility of Subcommittee E10.93 on Editorial.

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[2] ICRU Report 60 has been superseded by ICRU Report 85a on "Fundamental Quantities and Units for Ionizing Radiation," October 2011. Both of these documents are available from International Commission on Radiation Units and Measurements (ICRU), 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814.

[3] Document produced by Working Groups of the Joint Committee for Guides in Metrology (JCGM). Available free of charge at BIPM website (http://www.bipm.org).

[4] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[5] The last approved version of this historical standard is referenced on www.astm.org.

1.3 *ICRU Documents:*[2]

ICRU 60 Fundamental Quantities and Units for Ionizing Radiation, December 30, 1998

ICRU 85a Fundamental Quantities and Units for Ionizing Radiation, October, 2011

1.4 *NIST Document:*[6]

NIST Technical Note 1297 Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, 1994

1.5 *ISO Standard:*[7]

ISO 10012 Measurement management systems – Requirements for measurement processes and measuring equipment

2. Terminology

absorbed dose (*D*)**—**quotient of d$\bar{\varepsilon}$ by d*m*, where d$\bar{\varepsilon}$ is the mean incremental energy imparted by ionizing radiation to matter of incremental mass d*m*. (ICRU), thus

$$D = \mathrm{d}\bar{\varepsilon}/\mathrm{d}m \tag{1}$$

Discussion—The SI unit of absorbed dose is the gray (Gy), where 1 gray is equivalent to the absorption of 1 joule per kilogram of the specified material (1 Gy = 1 J/kg). The unit rad (1 rad = 100 erg/g = 0.01 Gy) is still widely used in the nuclear community; however, its continued use is not encouraged. For a photon source under conditions of charged particle equilibrium, the absorbed dose, *D*, may be expressed as follows:

$$D = \Phi \cdot E \cdot \mu_{en}/\rho, \tag{2}$$

where:

Φ = **fluence** (m^{-2}),
E = energy of the ionizing radiation (J), and
μ_{en}/ρ = **mass energy absorption coefficient** (m^2/kg).

If bremsstrahlung production within the specified material is negligible, the mass energy absorption coefficient (μ_{en}/ρ) is equal to the mass energy transfer coefficient (μ_{tr}/ρ), and absorbed dose is equal to kerma if, in addition, charged particle equilibrium exists.

absorbed dose rate ($\dot{D}$)—quotient of d*D* by d*t* where d*D* is the increment of absorbed dose in the time interval d*t* (ICRU), thus

$$\dot{D} = \mathrm{d}D/\mathrm{d}t \tag{3}$$

SI unit: Gy·s^{-1}.

Discussion—The absorbed-dose rate is often specified as an average value over a longer time interval, for example, in units of Gy·min^{-1} or Gy·h^{-1}.

accuracy—closeness of agreement between a measured **quantity value** and a true quantity value of a **measurand** (VIM).

Discussion—

(1) The concept "accuracy" is not a quantity and is not given a numerical quantity value. A measurement is said to be more accurate when it offers a smaller measurement error.

(2) The term "accuracy" should not be used for measurement trueness and the term "**precision**" should not be used for "accuracy," which, however, is related to both these concepts.

(3) "Accuracy" is sometimes understood as closeness of agreement between measured quantity values that are being attributed to the measurand.

activation cross section—cross section for a specific direct or compound nuclear interaction in which the product nucleus is radioactive.

Discussion—Fission and spallation processes produce a statistical ensemble of outgoing nuclear channels, but they are not considered to be activation reactions.

activity ***(A)—****of an amount of radionuclide in a particular energy state at a given time*, quotient of –d*N* by d*t*, where d*N* is the mean change in the number of nuclei in that energy state due to spontaneous nuclear transformations in the time interval d*t* (ICRU), thus

$$A = -\mathrm{d}N/\mathrm{d}t \tag{4}$$

Unit: s^{-1}

The special name for the unit of activity is the becquerel (Bq), where

$$1\ \mathrm{Bq} = 1\ \mathrm{s}^{-1} \tag{5}$$

Discussion—The former special unit of activity was the curie (Ci), where

$$1\ \mathrm{Ci} = 3.7 \times 10^{10}\ \mathrm{s}^{-1}\ (\text{exactly}). \tag{6}$$

The negative sign in Eq 4 is an indication that the activity is decreasing with time. The "particular energy state" is the ground state of the nuclide unless otherwise specified. The activity of an amount of radionuclide in a particular energy state is equal to the product of the decay constant for that state and the number of nuclei in that state (that is, $A = N\lambda$). (See **decay constant**.)

aleatory uncertainty—uncertainty representing random uncertainty contributors where there is little possibility of reducing this uncertainty contributor by consideration of a more controlled scenario.

Discussion—

(1) One paradigm decomposes uncertainty into epistemic and aleatory components. This division of uncertainty categories is very dependent upon what question is being posed in a given application. Aleatory uncertainties can be transformed into epistemic uncertainties depending upon the application. The uncertainties underlying a quantity may be classified as aleatory or epistemic according to the goals of the process.

(2) Aleatory uncertainty, also referred to as variability, stochastic uncertainty or irreducible uncertainty, is used to describe inherent variation associated with a quantity or phenomenon of interest. The determination of material properties or operating conditions of a physical system typically leads to aleatory uncertainties; additional experimental characterization might provide more conclusive description of the variability but cannot eliminate it completely. Aleatory uncertainty is normally characterized using probabilistic approaches.

analysis bandwidth—spectral band used in an instrument, such as a densitometer, for a measurement.

analysis wavelength—wavelength used in a spectrophotometric instrument for the measurement of optical absorbance or reflectance.

annihilation radiation—gamma radiation produced by the annihilation of a positron and an electron.

[6] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, USA, http://www.nist.gov

[7] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.