
Nanotechnologies — Vocabulary —
Part 2:
Nano-objects

Nanotechnologies — Vocabulaire —
Partie 2: Nano-objets

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Contents

	Page
Foreword	iv
Introduction	vi
1 Scope	1
2 Core terms related to particles	1
3 Terms concerning particles and assemblies of particles	1
4 Terms specific to nano-objects	2
Annex A (informative) Particle size measurement	5
Annex B (informative) Agglomerates, aggregates, and constituent particles	8
Annex C (informative) Index	9
Bibliography	10

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committees responsible for this document are ISO/TC 229, *Nanotechnologies* and Technical Committee IEC/TC 113, *Nanotechnology standardization for electrical and electronic products and systems*. The draft was circulated for voting to the national bodies of both ISO and IEC.

This first edition of ISO/TS 80004-2 cancels and replaces ISO/TS 27687:2008, which has been technically revised.

Documents in the 80000 to 89999 range of reference numbers are developed by collaboration between ISO and IEC.

ISO/TS 80004 consists of the following parts, under the general title *Nanotechnologies — Vocabulary*:

- *Part 1: Core terms*
- *Part 2: Nano-objects*
- *Part 3: Carbon nano-objects*
- *Part 4: Nanostructured materials*
- *Part 5: Nano/bio interface*
- *Part 6: Nano-object characterization*
- *Part 7: Diagnostics and therapeutics for healthcare*
- *Part 8: Nanomanufacturing processes*

The following parts are under preparation:

- *Part 9: Nano-enabled electrotechnical products and systems*
- *Part 10: Nano-enabled photonic components and systems*
- *Part 11: Nanolayer, nanocoating, nanofilm, and related terms*

- *Part 12: Quantum phenomena in nanotechnology*
- *Part 13: Graphene and other two-dimensional materials*

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Introduction

It is predicted that applications of nanotechnologies may pervade all areas of life. In the areas of communication, health, manufacturing, materials and knowledge-based technologies, there is a need to provide industry and research with standardized vocabulary and nomenclature to aid the responsible development and application of the technologies. It is also essential that regulators such as health and environmental protection agencies have reliable measurement systems supported by well-founded and robust standards.

Often in the field of nanotechnologies, naming of materials seen on microscopic images is inspired by the shape of objects found in everyday life, although the physical size is much smaller. The prefix nano- is often added to denote the small size of the object. (The prefix nano- is also used in SI units to indicate 10^{-9} e.g. 1 nanometre = 10^{-9} metre.). Thus, the term “nanoscale” (2.1) has been defined to denote the length interval approximately from 1 nm to 100 nm.

To create a unitary vocabulary, this part of ISO 80004 encompasses terms used concerning particles with nanoscale dimensions. The terms in this part of ISO 80004 form part of a larger hierarchy of terms under development for nanotechnologies. These terms are intended to facilitate communications between organizations and individuals in industry and those who interact with them.

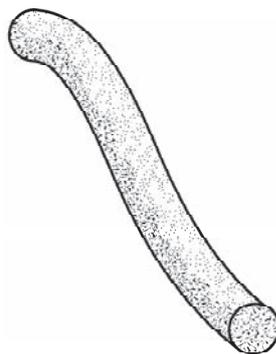
Objects with one or more external dimensions in the nanoscale can have properties that make them key components of materials and systems resulting in improved performance over their conventional counterparts. These *nano-objects* (2.2) often have properties that are not simple extrapolations of the properties of their larger form, with these novel properties called emerging, discontinuous or transformative properties.

The size and shape of nano-objects are often intrinsic to their function, so the description and measurement of their size and shape are important and must be considered carefully. The three most basic shapes referred to in this part of ISO 80004 are illustrated in Figure 1. These three simple shapes represent the main classes of structural dimensionality to help categorize nano-objects. Some other common shapes are defined in this part of ISO 80004, but a large number of different shapes are possible.

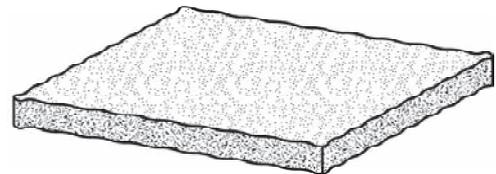
A number of other parameters in addition to size and shape are also intrinsic to the function and phenomena exhibited by nano-objects. These parameters include composition, morphology, crystalline structure, and surface features, which can all have a major influence on the key nanoscale phenomena exhibited by nano-objects. Such phenomena include magnetic, optical, catalytic, electronic, and other properties.



a) nanoparticle
(3 ext. dimensions
in the nanoscale)



b) nanofibre
(2 ext. dimensions
in the nanoscale)



c) nanoplate
(1 ext. dimensions
in the nanoscale)

Figure 1 — Schematic diagrams showing some shapes for nano-objects

A particular issue concerns nano-objects where one or more external dimensions are larger than the nanoscale. Potential confusion can occur when one of these dimensions greatly exceeds the nanoscale. For example, carbon nanotubes can have overall lengths in the millimetre range and are still nano-

objects according to the definitions in this part of ISO 80004. An example of an approach to this issue is to consider the size or shape at which the health risk from inhalation or other potential routes of exposure to nano-objects becomes small as an upper size limit for nano-objects.

It is acknowledged that a wide variety of approaches to definitions and classifications are applicable to particulate material and some of these regimes may also be relevant to nano-objects. Industrial, regulatory, and scientific domains often use terms such as coarse, fine and ultrafine to denote different size range fractions of *particles* (3.1). Thus for airborne particles, ultrafine particles, specified as PM_{0.1} (PM means “particulate matter”), refer to particles with aerodynamic diameters of 100 nm or less. Fine particles (PM_{2.5}) refer to particles with aerodynamic diameters of 2,5 µm or less and coarse particles (PM₁₀) refer to those with aerodynamic diameters of 10 µm or less. These size range fractions are used by regulators for risk assessment purposes in many contexts, including traffic pollution, volcanic ash, dust storms, industrial pollution and natural airborne allergens such as pollen.

In this Technical Specification, nano-objects are defined according to their shape as determined by nanoscale dimensionality. In addition, some types of nano-objects are also defined according to structural configuration, morphology, form or functionality. It is beyond the scope of this Technical Specification to consider or recommend specific size, size distribution, or related thresholds for nano-objects, particularly given the wide variability in size, shape, morphology, composition, and surface features of nano-objects, with each combination potentially presenting differing implications for assessments of risk or safety to health or the environment.

There is a hierarchical relationship between many of the different terms in this part of ISO 80004. Elements of this are shown in Figure 2 to illustrate some of the relationships that exist.

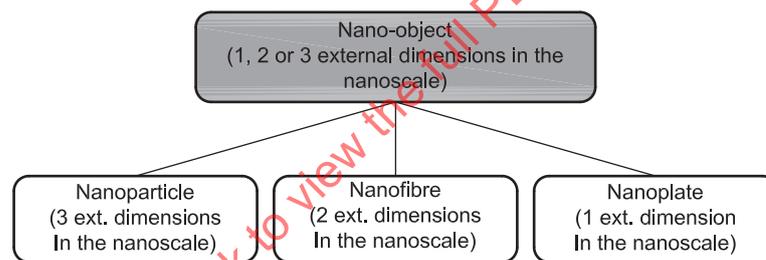


Figure 2 — Fragment of hierarchy of terms related to nano-objects

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Nanotechnologies — Vocabulary —

Part 2: Nano-objects

1 Scope

This Technical Specification lists terms and definitions related to particles in the field of nanotechnologies.

2 Core terms related to particles

2.1

nanoscale

length range approximately from 1 nm to 100 nm

Note 1 to entry: Properties that are not extrapolations from a larger size are predominantly exhibited in this length range.

[SOURCE: ISO/TS 80004-1:2010, 2.1]

2.2

nano-object

discrete piece of material with one, two or three external dimensions in the *nanoscale* (2.1)

Note 1 to entry: The second and third external dimensions are orthogonal to the first dimension and to each other.

[SOURCE: ISO/TS 80004-1:2010, 2.2]

3 Terms concerning particles and assemblies of particles

Nano-objects [for example nanoparticles, nanofibres, and nanoplates, (see [Clause 4](#))], often occur in (large) groups, rather than as isolated or distinct entities. For reasons of surface energy, such coexisting nano-objects are likely to interact. In the description of these interactions, the following terms are often used. The following terms are not restricted with respect to physical size and shape. These terms are included for completeness and importance at the nanoscale.

3.1

particle

minute piece of matter with defined physical boundaries

Note 1 to entry: A physical boundary can also be described as an interface.

Note 2 to entry: A particle can move as a unit.

Note 3 to entry: This general particle definition applies to *nano-objects* (2.2).

[SOURCE: ISO 26824:2013, 1.1]

3.2

primary particle

original source *particle* (3.1) of *agglomerates* (3.4) or *aggregates* (3.5) or mixtures of the two

Note 1 to entry: *Constituent particles* (3.3) of agglomerates or aggregates at a certain actual state may be primary particles, but often the constituents are aggregates.

ISO/TS 80004-2:2015(E)

Note 2 to entry: Agglomerates and aggregates are also termed secondary particles.

[SOURCE: ISO 26824:2013, 1.4]

3.3

constituent particle

identifiable, integral component of a larger *particle* (3.1).

Note 1 to entry: The constituent particle structures may be *primary particles* (3.2) or secondary particles.

3.4

agglomerate

collection of weakly or medium strongly bound *particles* (3.1) where the resulting external surface area is similar to the sum of the surface areas of the individual components

Note 1 to entry: The forces holding an agglomerate together are weak forces, for example van der Waals forces or simple physical entanglement.

Note 2 to entry: Agglomerates are also termed secondary particles and the original source particles are termed *primary particles* (3.2).

[SOURCE: ISO 26824:2013, 1.2]

3.5

aggregate

particle (3.1) comprising strongly bonded or fused particles where the resulting external surface area is significantly smaller than the sum of surface areas of the individual components

Note 1 to entry: The forces holding an aggregate together are strong forces, for example covalent or ionic bonds, or those resulting from sintering or complex physical entanglement, or otherwise combined former primary particles.

Note 2 to entry: Aggregates are also termed secondary particles and the original source particles are termed primary particles.

[SOURCE: ISO 26824:2013, 1.3, modified — Note 1 adapted.]

4 Terms specific to nano-objects

4.1

engineered nano-object

nano-object (2.2) designed for specific purpose or function

[SOURCE: ISO/TS 80004-1:2010, 2.8, modified]

4.2

manufactured nano-object

nano-object (2.2) intentionally produced to have selected properties or composition

[SOURCE: ISO/TS 80004-1:2010, 2.9]

4.3

incidental nano-object

nano-object (2.2) generated as an unintentional by-product of a process

Note 1 to entry: The process includes manufacturing, biotechnological or other processes.

[SOURCE: ISO/TS 80004-1:2010, 2.10, modified]

4.4**nanoparticle**

nano-object (2.2) with all external dimensions in the *nanoscale* (2.1) where the lengths of the longest and the shortest axes of the nano-object do not differ significantly

Note 1 to entry: If the dimensions differ significantly (typically by more than 3 times), terms such as *nanofibre* (4.5) or *nanoplate* (4.6) may be preferred to the term nanoparticle.

4.5**nanofibre**

nano-object (2.2) with two external dimensions in the *nanoscale* (2.1) and the third dimension significantly larger

Note 1 to entry: The largest external dimension is not necessarily in the nanoscale.

Note 2 to entry: The terms nanofibril and nanofilament can also be used.

Note 3 to entry: See 4.4 Note 1.

4.6**nanoplate**

nano-object (2.2) with one external dimension in the *nanoscale* (2.1) and the other two external dimensions significantly larger

Note 1 to entry: The larger external dimensions are not necessarily in the nanoscale.

Note 2 to entry: See 4.4 Note 1.

4.7**nanorod**

solid *nanofibre* (4.5)

4.8**nanotube**

hollow *nanofibre* (4.5)

4.9**nanowire**

electrically conducting or semi-conducting *nanofibre* (4.5)

4.10**nanoribbon****nanotape**

nanoplate (4.6) with the two larger dimensions significantly different from each other

Note 1 to entry: See 4.4 Note 1.

[SOURCE: ISO/TS 80004-3:2010, 2.10, modified.]

4.11**nanosphere**

spherical *nano-object* (2.2)

Note 1 to entry: For some hollow structures, the term nanocapsule is preferred.

4.12**nano-onion**

spherical *nanoparticle* (4.4) with concentric multiple shell structure

[SOURCE: ISO/TS 80004-3:2010, 2.8]

4.13

core-shell nanoparticle

nanoparticle (4.4) consisting of a core and shell(s)

Note 1 to entry: A related term *nanostructured core-shell particle* is defined in ISO/TS 80004-4.

Note 2 to entry: The largest external dimension/length (core diameter plus shell thickness) has to be in the *nanoscale* (2.1). For spherical core-shell nanoparticle, this length is the outer diameter.

4.14

nanocone

cone-shaped *nanofibre* (4.5) or *nanoparticle* (4.4)

[SOURCE: ISO/TS 80004-3:2010, 2.9]

4.15

nanocrystal

nano-object (2.2) with a crystalline structure

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Annex A (informative)

Particle size measurement

A.1 General

Particle size is a fundamental attribute of disperse materials. However, reported particle size and associated accuracy are dependent on a number of considerations.

A.1.1 Sampling and size distributions

Particles from either natural sources or when manufactured under carefully controlled conditions exist as populations with a range of sizes, shapes, morphologies, and compositions. For good quality measurement, a representative sample of a sufficient number of particles to adequately define the population must first be obtained. Also, the approach needed is affected by the medium surrounding the particles, and also if the particles are transferred from one medium to another. An example is the deposition of particles from liquid, air, or powder to a surface for exposure to a vacuum environment for electron microscopy. Particles might be altered by the different environments (e.g. semi volatile materials may out-gas) or agglomerates might be dispersed by shear forces during measurement (e.g. in the nozzle of a cascade impactor). The transfer of particles from one medium to another might also affect how representative the sample is of the original material.

A.1.2 Measurement principles and definition of measurand

The measured size of a particle is always dependent on the particular method that is being used to examine, measure, or visualize the particle. Particle size is measured by using one or a number of physical phenomena whose strength depends on the size of the particle being examined. Examples of different measurement principles for nano-objects are diffusion velocity in liquids, electrophoretic mobility in gases or the BET (Brunauer, Emmett and Teller) surface area of a particle system. Any given particle will interact with its environment according to its own specific physical and chemical make-up. This means that the size of a particle reported by one technique may not be the same as the size when measured with another technique.

In many fields, it has been the custom to define particle size ranges with common behaviour, sources, or composition with the method of measurement embedded in the definition. An example is the term ultrafine particles defined as particles with equivalent diameters smaller than 100 nm. Equivalent diameter refers to the practice of reporting the size of a particle of unknown composition or shape as if the particle had known composition and spherical shape. For example, when the particles are measured with an inertial based instrument, aerodynamic diameter is an equivalent diameter computed as if the particle had unity specific density and spherical shape corresponding to the measured particle settling velocity. It is confusing that the term ultrafine particle is sometimes used interchangeably with the term nanoparticle.

An additional complication is that even with a single detection method, the result depends on how the information is processed. An example is the image obtained with a microscope. Quite different results may be obtained with respect to the method used to interpret the image, e.g. maximum versus minimum length of a complex particle, which are both useful but nevertheless are different measurands. In the same way as equivalent diameters, length parameters used for particle size characterization should be indicated.^[5]

As particles normally occur in populations as mentioned above, the distribution of size needs to be characterized, for instance by statistical distribution parameters such as mean and standard deviation.

The selection of a mathematical form or parameters of the distribution function depends on the particular measurement requirements.

The proportions of the size classes in a population are based on the measurement type that is determined mainly by the measurement method, e.g. number for optical counting methods. Other measurement types are volume for ultrasonic spectroscopy or scattered light intensity for optical ensemble methods, which can depend on the 2nd up to the 6th power of the particle size. The necessary assumptions included in the instrument software for the conversion of that intensity based distributions into number or volume based distributions should be considered for the measured particles.

A.1.3 Conclusions

Measurement of particle size is a complex issue due to the fact that a large number of different indirect measurement techniques are available. This makes comparison of results from one laboratory to another difficult when different measurement methods are used, particularly when reference materials are not available. For most particle sizing methods, because of the issues described above, unambiguous metrological traceability of the measurement result to the SI unit of length is difficult to establish.

When reporting particle size measurement results, it is therefore necessary to describe the method used to determine the particle size. Often the planned use of the particle size data, e.g. product requirements or health effects, will dictate selection of the particular measurement method that is used.

A.1.4 Reference to other relevant ISO Technical Committees

ISO general standards for individual particle characterization methods and standards for the representation of results are prepared by ISO/TC 24/SC 4 *Particle Characterization*.

Standards for specific application branches of particle technology are prepared by ISO/TC 146/SC 2 *Air Quality — Workplace Atmospheres* and ISO/TC 209 *Cleanrooms and associated controlled environments*.

A.2 Other terms

A.2.1 Terms related to measurement issues for particle size

There are other terms related to measurement issues for particles that are defined in other ISO standards. Some of these terms are given below for information.

A.2.2 ultrafine particle

particle (3.1) with an equivalent diameter less than 0.1 μm

[SOURCE: ISO 14644-3:2005, 3.2.12]

Note 1 to entry Most *nanoparticles* (4.4), defined by their geometrical dimensions, are ultrafine particles, when measured.

Note 2 to entry For example, a polystyrene sphere of 100 nm diameter represents the upper limit for the nanoparticle definition as well as for the ultrafine particle definition that addresses aerodynamic or mobility equivalent diameters. Porous particles have smaller equivalent optical and aerodynamic diameters than non-porous particles. Nonporous particles with higher density than polystyrene will have larger aerodynamic equivalent diameters.

A.2.3 equivalent spherical diameter

diameter of a sphere having the same physical properties as the particle in the measurement

Note 1 to entry Physical properties are for instance the same settling velocity or electrolyte solution displacing volume or projection area under a microscope.

Note 2 to entry The physical property to which the equivalent diameter refers shall be indicated using a suitable subscript, for example x_s for equivalent surface area diameter or x_v for equivalent volume diameter.

[SOURCE: ISO 26824:2013, 1.6]

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Annex B (informative)

Agglomerates, aggregates, and constituent particles

Figure B.1 illustrates how particles can consist of different types of aggregates and agglomerates as well as individual particles.

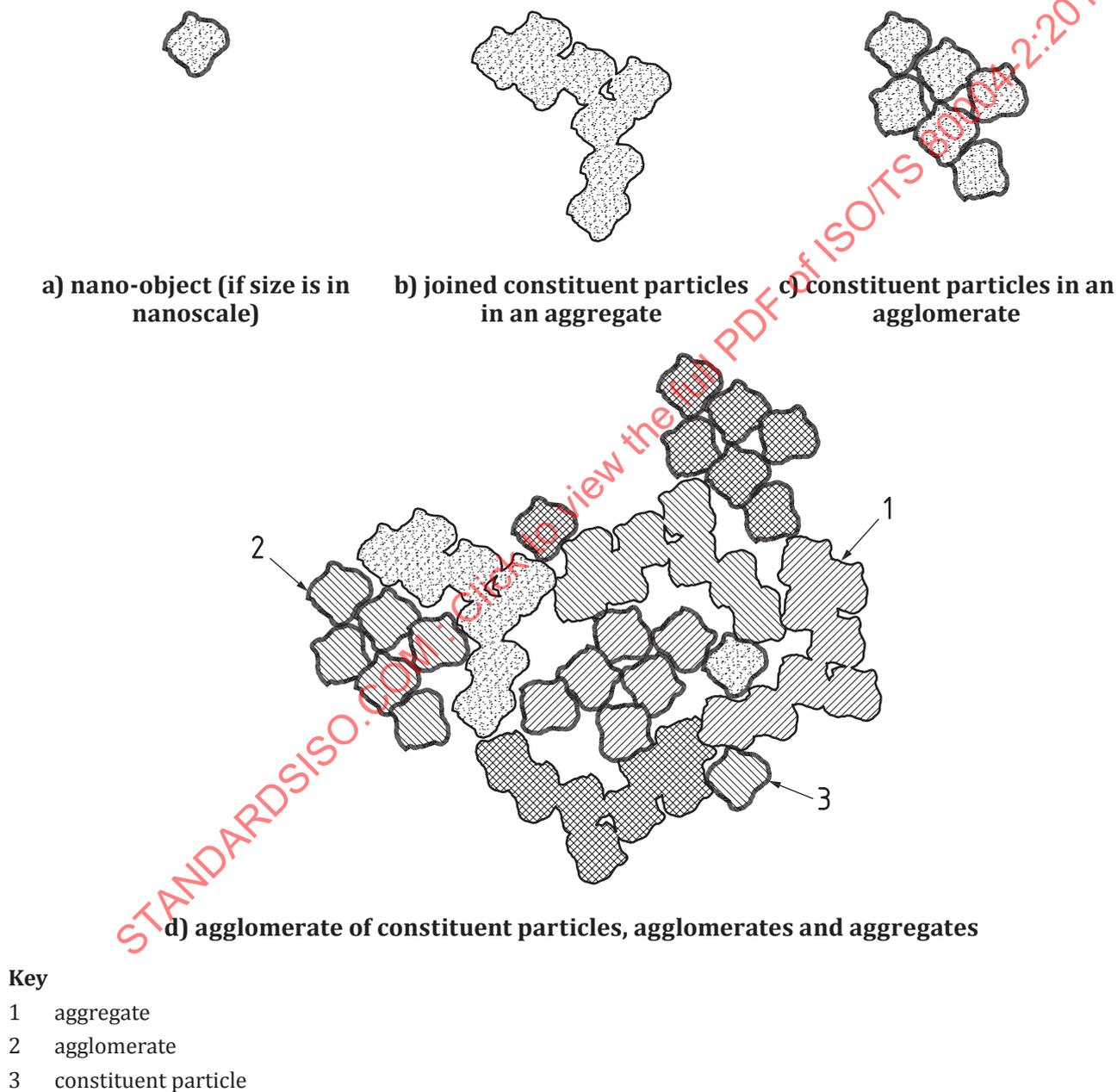


Figure B.1 — Types of particles