भारतीय मानक
Indian Standard

IS 17567 (Part 1) : 2021
ISO/TS 19807-1 : 2019

नैनोटेक्नोलॉजी — चुम्बकीय नैनोमैटेरियल

भाग 1 चुम्बकीय नैनोसॅस्पेंशन के लाक्षणिक एवं मापन की विशिष्टि

Nanotechnologies — Magnetic Nanomaterials

Part 1 Specification of Characteristics and Measurements for Magnetic Nanosuspensions

ICS 07.120

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NATIONAL FOREWORD

This Indian Standard (Part 1) which is identical to ISO/TS 19807-1 : 2019 Nanotechnologies — Magnetic nanomaterials — Part 1: Specification of characteristics and measurements for magnetic nanosuspensions' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on recommendation of the Nanotechnologies Sectional Committee, and approval of the Metallurgical Engineering Division Council.

The committee has decided to adopt this standard under dual numbering system and make it align with ISO/TS 19807-1 : 2019.

The text of ISO Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain terminologies and conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

NANOTECHNOLOGIES — MAGNETIC NANOMATERIALS

PART 1 SPECIFICATION OF CHARACTERISTICS AND MEASUREMENTS FOR MAGNETIC NANOSUSPENSIONS

1 Scope

This document specifies the characteristics of magnetic nanosuspensions to be measured and lists measurement methods for measuring these characteristics.

This is a generic document and does not deal with any particular application.

2 Normative references

There are no normative references for 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 http://www.electropedia.org/

3.1
AC susceptibility
complex ratio between the dynamic magnetization and the applied magnetic excitation field

Note 1 to entry: The dynamic magnetization is given as $M = M_0 \mathrm{e}^{(i2\pi \mathrm{ft} - \phi)}$ and the applied magnetic excitation field is given as $H = H_0 \mathrm{e}^{i2\pi \mathrm{ft}}$. The AC susceptibility $\chi = \mathrm{M} / \mathrm{H}$ is divided into an in-phase component (real part) and an out-of-phase component (imaginary part): $\chi = \chi' - i\chi''$.

Note 2 to entry: In dependence on the type of magnetization that is used, the AC susceptibility of a material is related to volume, mass or amount of the material.

AC volume susceptibility $$\chi_{\mathrm{V}} = \frac{M_{0\mathrm{V}}}{H_0} \cos\varphi - i \frac{M_{0\mathrm{V}}}{H_0} \sin\varphi$$

AC mass susceptibility $$\chi_{\mathrm{m}} = \frac{M_{0\mathrm{m}}}{H_0} \cos\varphi - i \frac{M_{0\mathrm{m}}}{H_0} \sin\varphi$$

AC molar susceptibility $$\chi_{\mathrm{n}} = \frac{M_{0\mathrm{n}}}{H_0} \cos\varphi - i \frac{M_{0\mathrm{n}}}{H_0} \sin\varphi$$

Note 3 to entry: AC susceptibility depends on the excitation field frequency and the temperature, which should also be indicated.

Note 4 to entry: The amplitude of the excitation field must be small enough so there is a linear relation between the amplitude of the dynamic magnetization and the amplitude of the applied AC field.

3.2
agglomerate
collection of weakly or medium strongly bound particles 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.

Note 3 to entry: Primary particles can themselves be composites particles with both magnetic and non-magnetic parts.

[SOURCE: ISO/TS 80004-2:2015,3.4]

3.3
aggregate
particle 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/TS 80004-2:2015,3.5]

3.4
chemical composition
ratio of the quantities of the chemical elements present in the nanosuspension

Note 1 to entry: The quantities may be expressed in mass, volumen or number of moles.

3.5
core-shell nanoparticle
nanoparticle 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 twice the shell thickness) has to be in the nanoscale . For spherical core-shell nanoparticle, this length is the outer diameter.

Note 3 to entry: A related term, single-core magnetic nanoparticle, is defined in reference [1].

[SOURCE: ISO/TS 80004-2:2015,4.13]

3.6
curie temperature
temperature at which a ferromagnetic material passes from the ferromagnetic state to the paramagnetic state and vice versa

[SOURCE: ISO 11358-1:2014, 3.3]

3.7
differential magnetic susceptibility
differential ratio of the magnetization that is induced by a magnetic field change to the amplitude of the magnetic field change

Note 1 to entry: The magnetic susceptibility of a material can be related to volume, mass or amount of the material.

volume susceptibility $\chi_{\mathrm{V}} = \frac{dM_{\mathrm{V}}}{dH}$

mass susceptibility $\chi_{\mathrm{m}} = \frac{dM_{\mathrm{m}}}{dH}$

molar susceptibility $\chi_{\mathrm{n}} = \frac{dM_{\mathrm{n}}}{dH}$

Note 2 to entry: The initial susceptibility χo is defined as the susceptibility at H = 0.

Note 3 to entry: Magnetic nanosuspensions are considered as magnetically isotropic and their magnetic susceptibility is indicated as a scalar.

3.8
dispersant
additive that facilitates the dispersion of solid in the dispersing medium, and that increases the stability against agglomeration of the mixture thereafter

[SOURCE: ISO 4618: 2014, 2.85, modified]

3.9
dispersing medium
liquid in which the sample is dispersed and suspended

[SOURCE: ISO 14703:2008, 3.5]

3.10
dry matter content
ratio of the mass of residues after drying at certain high temperature to that of sample before drying

3.11
dynamic viscosity
ratio between the applied shear stress and rate of shear of a liquid

Note 1 to entry: It is sometimes called the coefficient of dynamic viscosity, or simply viscosity.

Note 2 to entry: Dynamic viscosity is a measure of the resistance to flow or deformation of a liquid.

Note 3 to entry: The term dynamic viscosity can also be used in a different context to denote a frequency-dependent quantity in which shear stress and shear rate have a sinusoidal time dependence.

[SOURCE: ISO 3104:1994, 3.3, modified]

3.12
equivalent diameter
diameter of a sphere that produces a response by a given particle-sizing method, that is equivalent to the response produced by the particle being measured

Note 1 to entry: The physical property to which the equivalent diameter refers is indicated using a suitable subscript (see ISO 9276-1:1998).

Note 2 to entry: For discrete-particle-counting, light-scattering instruments, an equivalent optical diameter is used.

Note 3 to entry: Other material constants like density of the particle are used for the calculation of the equivalent diameter like Stokes diameter or sedimentation equivalent diameter. The material constants, used for the calculation, should be reported additionally.

[SOURCE: ISO/TS 80004-6:2013, 3.1.5]

3.13
fluid density
mass of unit volume of suspension at specific temperature

3.14
fluid nanodispersion
heterogeneous material in which nano-objects or a nanophase are dispersed in a continuous fluid phase of a different composition

[SOURCE: ISO/TS 80004-4:2011, 3.5]

3.15
freezing point
temperature at which solid crystals form within the dispersing medium as the liquid nanoparticle suspension is cooled under specified conditions of test

3.16
hydrodynamic diameter
equivalent diameter of a particle in a liquid having the same diffusion coefficient as the real particle in that liquid

[SOURCE: ISO/TS 80004-6:2013, 3.2.6]

3.17
magnetic moment
vector quantity describing the ability of a magnetized body to produce a magnetic field outside its own boundaries

3.18
magnetic nanoparticle
Nanoparticles with coupled atomic magnetic moment

3.19
magnetic field hyperthermia
the process where a time varying magnetic field of frequency f and amplitude H_o results in a temperature T increase of a magnetic nanosuspension

3.20
magnetization
vector quantity describing the specific magnetic moment of a material

Note 1 to entry: The magnetic moment of a sample can be related to volume, mass or amount of substance of the sample to obtain the magnetization.

volume magnetization $M_\mathrm{V} = \frac{\mu_\mathrm{m}}{V}$

mass magnetization $M_\mathrm{m} = \frac{\mu_\mathrm{m}}{m}$

molar magnetization $M_\mathrm{n} = \frac{\mu_\mathrm{m}}{n}$

Note 2 to entry: The magnetization should be indicated for sufficiently homogeneous compartments of the sample and those compartments should be mentioned (e.g. magnetization of the nanoparticle cores).

3.21
magnetoviscosity
dynamic viscosity of a liquid suspension of magnetic nanoparticles in the presence of external magnetic field

3.22
multi-core nanoparticle
core-shell nanoparticle with more than one physically separated core embedded in a matrix of shell material

3.23
nanoparticle
nano-object with all external dimensions in the nanoscale 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 or nanoplate may be preferred to the term nanoparticle.

[SOURCE: ISO/TS 80004-2:2015, 4.4]

3.24
nanophase
physically or chemically distinct region or collective term for physically distinct regions of the same kind in a material with the discrete regions having one, two or three dimensions in the nanoscale

Note 1 to entry: Nano-objects embedded in another phase constitute a nanophase.

[SOURCE: ISO/TS 80004-4:2011, 2.12]

3.25
nano-object
discrete piece of material with one, two or three external dimensions in the nanoscale

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

[SOURCE: ISO/TS 80004-2:2015,2.2]

3.26
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 80004-1:2015, 2.1]

3.27
nanosuspension
fluid nanodispersion (3.14) where the dispersed phase is a solid

Note 1 to entry: The use of the term "nanosuspension" carries no implication regarding thermodynamic stability.

[SOURCE: ISO/TS 80004-4:2011, 3.5.1]

3.28
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.

[SOURCE: ISO/TS 80004-2:2015,3.1]

3.29
particle size
linear dimension of a particle determined by a specified measurement method and under specified measurement conditions

Note 1 to entry: Different methods of analysis are based on the measurement of different physical properties. Independent of the particle property actually measured, the particle size can be reported as a linear dimension, e.g. as the equivalent spherical diameter.

Note 2 to entry: Particle size can be core diameter or hydrodynamic diameter depending on the application.

[SOURCE: ISO/TS 80004-6:2013,3.1.1]

3.30
particle size distribution
distribution of particles as a function of particle size

Note 1 to entry: Particle size distribution may be expressed as cumulative distribution or a distribution density (distribution of the fraction of material in a size class, divided by the width of that class).

Note 2 to entry: Particle size distribution can be both number based and mass based.

[SOURCE: ISO/TS 80004-6:2013, 3.1.2, modified]

3.31
particle volume fraction
volume percentage of particles per unit volume of nanosuspension

3.32
pH
measure of the activity of hydrogen ions in solution

Note 1 to entry: Adapted from ISO 80000-9.

Note 2 to entry: Whether a solution is acidic or alkaline is determined by the activity of the hydrogen ions present.

3.33
pour point
lowest temperature at which a magnetic nanosuspension will continue to flow when it is cooled under specified conditions

Note 1 to entry: The results may depend on the measurement conditions.

[SOURCE: ISO 5598:2008, 3.2.533]

3.34
pyromagnetic coefficient
Cchange of the volume magnetization temperature in constant magnetic field

Note 1 to entry: pyromagnetic coefficient is given by the following expression:

$$\kappa = \frac{dM_{\mathrm{v}}}{dT}$$

where

M_{v} is volume magnetization of the material;

T is temperature of the materialC.

3.35
relaxivity
difference in NMR relaxation rate of a magnetic nanoparticle suspension to the NMR relaxation rate of the pure dispersing medium normalized to the amount of substance concentration of the magnetic nanoparticles

Note 1 to entry: Relaxivity is given by the following formulae:

Longitudinal relaxivity: $$r_1 = \left(\frac{1}{T_1} - \frac{1}{T_{1,D}} \right) \cdot \frac{1}{c}$$

Transverse relaxivity: $$r_2 = \left(\frac{1}{T_2} - \frac{1}{T_{2,D}} \right) \cdot \frac{1}{c}$$

Note 2 to entry: The temperature and the static magnetic field during the measurement have to be indicated.

Note 3 to entry: $T_{1,\mathrm{D}}$ and $T_{2,\mathrm{D}}$ are the longitudinal and transverse NMR relaxation times of the pure dispersing medium respectively.

Note 4 to entry: c is the amount of substance concentration.

3.36
saturation magnetization
constant magnetization value that is reached when a sufficiently high magnetic field H is applied to an ensemble of magnetic nanoparticles and the magnetic moments of the nanoparticles align to the field

Note 1 to entry: The saturation magnetization is only indicated for the nanoparticle compartment of the magnetic nanosuspension.

Note 2 to entry: The saturation magnetization to be reported together with the magnetizing field which is applied and together with the measurement temperature.

3.37
shelf life
recommended time period during which a product (suspension) can be stored, throughout which the defined quality of a specified characteristics of the product remains acceptable under expected (or specified) conditions of distribution, storage, display and usage

Note 1 to entry: Defined characteristics should be measured after fixed time intervals.

3.38
single-core nanoparticle
core-shell nanoparticle with a single core

3.39
specific heat capacity (at constant pressure)
heat capacity divided by mass

Note 1 to entry: It is given by the following formula:

$$c_\mathrm{p} = m^{-1}(dQ/dT)_\mathrm{p} \tag{1}$$

where

m is the mass of material;

c_p is the specific heat capacity and is expressed in kilojoules per kilogram per K ($kJ \cdot kg^{-1} \cdot K^{-1}$) or in joules per gram per K ($J \cdot g^{-1} \cdot K^{-1}$); subscript p indicates an isobaric process;

dQ is the quantity of heat necessary to raise the temperature of the material by dT.

Note 2 to entry: This formula is valid in a temperature range where a material shows no first order phase transition.

$$(dQ/dT) = (dt/dT) \times (dQ/dt) = (\text{heating rate})^{-1} \times (\text{heat flow rate}) \quad (2)$$

Note 3 to entry: At phase transitions, there is a discontinuity in the specific heat capacity. Part of the heat is consumed to produce a material state of higher energy and it is not all used in raising the temperature. For this reason, the specific heat capacity can only be determined properly outside regions of phase transitions.

[SOURCE: ISO 80000-5:2007, modified]

3.40
specific loss power
heating power of a magnetic nanosuspension per unit mass in response to a time varying magnetic field of frequency f and amplitude Ho in the context of magnetic field hyperthermia

Note 1 to entry: The unit mass can relate to the whole nanosuspension, to the solid content or to other compartments of the nanosuspension. It should be indicated which mass is used in reporting the specific loss power.

Note 2 to entry: In addition to the specific loss power, the intrinsic loss power may be reported, which is given by the equation: $ILP = SLP/(f \cdot H_0^2)$.

Note 3 to entry: When reporting the specific loss power or intrinsic loss power parameter, also the initial temperature of the magnetic nanosuspension before the heating as well as frequency f and amplitude H_0 of the excitation field should be indicated.

3.41
surface functionality
presence of chemical functional groups on the surface of particles

3.42
suspension
heterogeneous mixture of materials comprising a liquid and a finely dispersed solid material

[SOURCE: ISO 4618:2014, 2.246]

Note 1 to entry: solid material may be magnetic nanoparticles or composite material containing magnetic nanoparticles.

3.43
thermal conductivity
density of heat flow rate divided by the temperature gradient

[SOURCE: ISO 8894-2:2007, 2.1]

3.44
zeta potential
difference in electric potential between that at the slipping plane and that of the bulk liquid

Note 1 to entry: Slipping plane is the abstract plane in the vicinity of the liquid/solid interface where liquid starts to slide relative to the surface under influence of a shear stress.

[SOURCE: ISO 13099-1:2012, 2.1.8]

4 Symbols and abbreviated terms

For the purposes of this document, the following symbols and abbreviations apply.

Table 1 — Abbreviations

Abbreviation	Full Name
ACS	AC susceptibility measurement
DLS	Dynamic light scattering
EDS	Energy dispersive X-ray spectroscopy
ICP-OES	Inductively coupled plasma optical emission spectroscopy
ICP-MS	Inductively coupled plasma mass spectroscopy
IR	Infrared
MFH	Magnetic field hyperthermia
NMR	Nuclear magnetic resonance
SAXS	Small angle X–ray scattering
SLP	Specific loss power
SQUID	Superconducting quantum interference device
TEM	Transmission electron microscopy
TGA	Thermogravimetric analysis
VCM	Vibrating coil magnetometry
VSM	Vibrating sample magnetometry
XRD	X-ray diffraction
XRF	X-ray fluorescence spectroscopy

Table 2 — Symbols

Symbol	Parameter	SI Unit
c	Amount concentration	Molar: mol l^{-1}, Mass: g ml^{-1}
c_p	Specific heat capacity (at constant pressure)	J kg^{-1} K^{-1}
f	Frequency	Hz
H_0	Magnetic field amplitude	Am^{-1}
M_m	Mass magnetization	A m^2 kg^{-1}
M_n	Molar magnetization	A m^2 mol^{-1}
M_s	Saturation magnetization	Volume: A m^{-1}, Mass: A m^2 kg^{-1}, Molar: A m^2 mol^{-1}
M_v	Volume magnetization	A m^{-1}
M_{0m}	Amplitude of dynamic mass magnetization	A m^2 kg^{-1}
M_{0n}	Amplitude of dynamic molar magnetization	A m^2 mol^{-1}
M_{0v}	Amplitude of dynamic volume magnetization	A m^{-1}
r_1	Longitudinal relaxivity	L mol^{-1} s^{-1}
r_2	Transverse relaxivity	L mol^{-1} s^{-1}
T	Temperature	K
T_B	Blocking temperature	K
T_c	Curie temperature	K
T_F	Freezing point	K
T_1	Longitudinal relaxation time	s
T_2	Transverse relaxation time	s

Table 2 *(continued)*

Symbol	Parameter	SI Unit
t	Time	s
η	Dynamic viscosity	kg m^{-1} s^{-1}
η_M	Magnetoviscosity	kg m^{-1} s^{-1}
κ	Pyromagnetic coefficient	A m^{-1} K^{-1}
Λ	Thermal conductivity	W m^{-1} K^{-1}
μ_m	Magnetic moment	A m^2
ζ	Zeta potential	V
ρ	Fluid density	kg m^{-3}
φ	Phase angle	radians
χ_m	Magnetic mass susceptibility	m^3 kg^{-1}
χ_n	Magnetic molar susceptibility	m^3 mol^{-1}
χ_v	Magnetic volume susceptibility	1
ILP	Intrinsic loss power	H m^2 kg^{-1}
SLP	Specific loss power	W/g

5 Characteristics and measurement methods of magnetic nanosuspensions

5.1 Table 3 lists characteristics and their measurement methods with standard guidelines.

Characteristics shall be selected from Table 3 depending on the application, and may be mutually agreed upon between interested parties.

The measurement methods and measurement conditions for determining those characteristics shall be mutually agreed upon between the interested parties.

Measurement method(s) used to determine each given characteristic may be selected from Table 1.

5.2 Other characteristics and measurement methods not included in Table 3 may be included in agreements between interested parties.

5.3 Attention is drawn to the existence of laboratory accreditation systems, for example in accordance with ISO/IEC 17025. Consideration should be given to the application of such a system to the characterization and measurement methods described in this document.

Table 3 — Characteristics

No.	Characteristics	Measurement Method	Guidelines
1.	Amount concentration of magnetic nanoparticles	TGA	[a]
		ICP-OES	[a]
		VSM	[a]
		ICP-MS	[a]
		SQUID magnetometry	[a]
		Spectrophotometry	[a]
2.	Chemical composition	IR spectroscopy	[a]
		TGA	[a]
		Mössbauer spectroscopy	[a]
		XRF	[a]

Table 3 *(continued)*

No.	Characteristics	Measurement Method	Guidelines
		XRD	a
		Raman spectroscopy	a
		spectrophotometry	a
		ICP-OES	a
		ICP-MS	a
		EDS	ISO 22309:2011
3.	Curie Temperature	VSM, SQUID magnetometry, VCM	a
4.	Differential magnetic susceptibility	VSM, SQUID magnetometry, VCM	a
5.	Dry matter content	TGA	a
6.	Dynamic Viscosity	parallel plate rheometry	a
		capillary viscometry	a
		rotational viscometry	ISO 6388:1989
7.	Fluid density	capillary-stoppered pycnometry, graduated bicapillary pycnometry vibration type densimetry	a
		hydrometry	a
8.	Freezing point	Thermometry	a
9.	Hydrodynamic diameter	DLS	ISO 22412: 2017
10.	Magnetoviscosity	magnetorheometry	a
11.	Particle size distribution	DLS	ISO 22412: 2017
		ICP-MS	ISO/TS 19590[d]
		TEM	ISO/WD 21363[d]
		ACS	a
		SAXS	ISO 17867:2015
12.	Particle Size	TEM	ISO/WD 21363[d]
		DLS	ISO 22412:2017
		laser diffraction	ISO 13320: 2009
		SAXS	ISO 17867:2015
		ACS	a
		VSM	a
13.	Particle volume fraction[c]	VSM, SQUID magnetometry, VCM	a
14.	pH	pH measurement methods	IEC 62434:2006
15.	Pour point	—	a
16.	Pyromagnetic coefficient	VSM, SQUID magnetometry	a
17.	Relaxivity	NMR	a
18.	Saturation Magnetization	VSM, SQUID magnetometry, VCM	a
19.	Shelf life[b]	b	ISO/TR 13097:2013
20.	Specific heat capacity	calorimetry	a
21.	Specific loss power	MFH calorimetry	a
22.	Surface functionality	IR spectroscopy	a
23.	Thermal conductivity	calorimetry, Hot-wire method	a
24.	Zeta potential	electrophoretic light scattering	ISO 13099-2:2012
		acoustic methods	ISO 13099-3:2014

Table 3 *(continued)*

No.	Characteristics	Measurement Method	Guidelines
[a] No standard guidelines available. An agreement between the material manufacturer and the buyer or user of the material should be made to decide the procedure of testing.			
[b] A mutual agreement to be made in between interested parties for the defined characteristics to be measured and value of decay percentage in quality of defined characteristics of magnetic nanosuspension in recommended time period.			
[c] This is applicable only in the case of negligible organic content in magnetic nanoparticles.			
[d] ISO documents are under development. An agreement between manufacturer and consumer should be made to decide the procedure of testing.			
[e] The listed ISO standards for measurements have been generally applied for measurement of the characteristics of ordinary materials, and it should be noted that these ISO standards have not yet been fully validated for application to magnetic nanosuspension.			

6 Reporting

6.1 A report shall be delivered by the supplier to the buyer documenting the characteristics of the material as described in 5.1 of this document.

6.2 The report should contain the following information:

a) reference to this document, ISO/TS 19807-1:2019;

b) identification of the material and lot numbers;

c) name of the characteristics measured and a description of the measurement methods used;

d) listing of the measurement results;

e) summary of uncertainties in data;

f) laboratory quality system.

Annex A
(informative)

Components of liquid suspensions of magnetic nanoparticles

A.1 Figures A.1 and A.2 illustrate the principles of magnetic nanosuspensions.

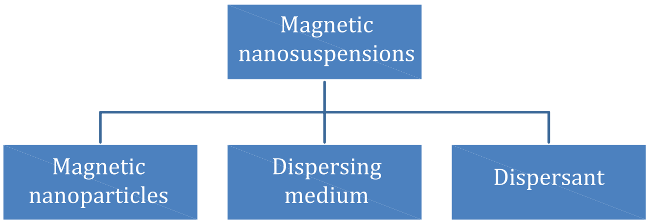
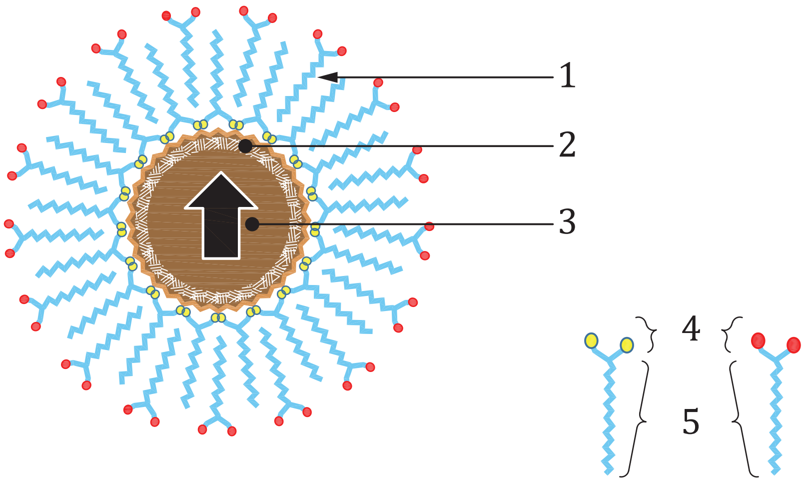


Figure A.1 — Chart shows the components of magnetic nanosuspensions

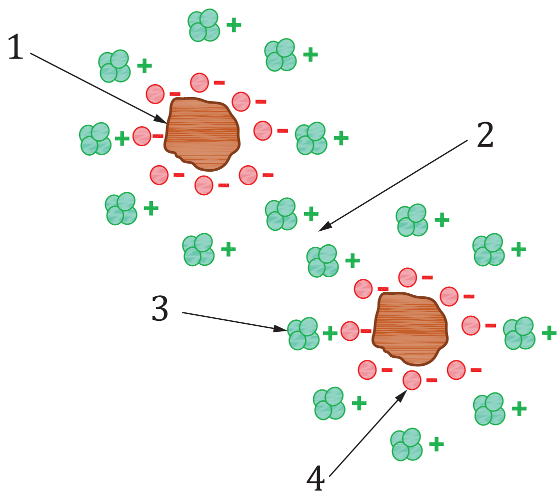
A.2 Magnetic nanoparticles are responsible for the magnetic behaviour of the suspension. In many cases, they have a metal oxide or metal core with coupled atomic magnetic moments. If the nanoparticle contains several cores, the nanoparticles are called multi-core nanoparticles, otherwise single-core nanoparticles.

A.3 Dispersing medium is the liquid part of the suspension. The choice of the dispersing medium depends on the application and temperature range, the suspension is to be used for. The suspension can be diluted by adding more dispersing medium.

A.4 Dispersants form the surfactant coating on the magnetic nanoparticles in the suspension. They serve the dual purpose of (1) preventing the formation of aggregates and agglomerates and (2) binding the solid content and the dispersing medium. In the case of biomedical applications, the outer surface of the dispersant can be functionalized with bioactive molecules. The dispersing mechanism can be steric, electrostatic or electristeric in nature.



a) The magnetic core encapsulated in a shell layer[2]



b) Electrostatic repulsion induced in ionic suspension of magnetic nanoparticles to form a stable suspension.

Key

a)

1 surfactant
2 dead layer
3 ferrimagnetic core with net moment
4 polar head
5 non-polar tail

b)

1 magnetic nanparticle
2 electrostatic repulsion
3 cation
4 anion

Figure A.2 — Depiction of suspension mechanisms

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[10] ISO 13099-2, *Colloidal systems — Methods for zeta-potential determination — Part 2: Optical methods*

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[12] ISO 13320, *Particle size analysis — Laser diffraction methods*

[13] ISO 14703, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Sample preparation for the determination of particle size distribution of ceramic powders*

[14] ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

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[17] ISO/DIS 21363:2018, *Nanotechnologies —Measurements of particle size and shape distributions by transmission electron microscopy*

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