
Rare earth — Vocabulary —
Part 2:
Metals and their alloys

Terres rares — Vocabulaire —
Partie 2: Métaux et alliages

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Published in Switzerland

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Foreword

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This document was prepared by Technical Committee ISO/TC 298, *Rare earth*.

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Introduction

Rare earth metals and their alloys are key raw materials for developing high-performance rare earth functional materials, such as hydrogen-storage materials, magnetic materials and superconducting materials, and are widely used in fields such as sustainable energy, robotics and electronic information.

Rare earth metals are also important additive elements for aluminium-base, magnesium-base, copper-base, titanium-base and other alloys.

This document specifies terms for use by producers, consumers and traders in the field of rare earth metals and their alloys. This document will serve as a reference that will help to reduce discrepancies or trade disputes caused by inconsistencies in terms used when dealing with rare earth metals and their alloys.

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Rare earth — Vocabulary —

Part 2: Metals and their alloys

1 Scope

This document defines the terms for rare earth metals and their alloys, as well as for methods of preparation and purification.

This document can be used as a reference to unify technical terms in rare earth production, application, inspection, circulation, trading, scientific research and education.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

rare earth impurity

undesirable rare earth element present in a *rare earth metal* (4.1) or *rare earth alloy* (5.1) other than the specified or target rare earth element(s)

3.2

non-rare earth impurity

undesirable non-rare earth element present in a *rare earth metal* (4.1) or *rare earth alloy* (5.1)

3.3

interstitial impurity

undesirable, non-metallic element such as hydrogen, boron, carbon, nitrogen or oxygen occupying interstitial positions in the lattice of a *rare earth metal* (4.1) or *rare earth alloy* (5.1)

3.4

rare earth metal content

total rare earth metal content

mass fraction of rare earth elements in a *rare earth metal* (4.1) or *rare earth alloy* (5.1)

Note 1 to entry: It is generally provided as a percentage of the metal, i.e. % TREM.

3.5

average atomic mass of rare earths in mixed rare earth metals or alloys

$\bar{M}$

ratio of the total mass of rare earth elements to their total number of moles, as shown by the formula:

$$\bar{M} = \frac{m_{\text{total}}}{n_{\text{total}}} = \frac{\sum_{i=1}^N m_i}{\sum_{i=1}^N \frac{m_i}{M_i}} = \frac{m_1 + m_2 + \dots + m_N}{\frac{m_1}{M_1} + \frac{m_2}{M_2} + \dots + \frac{m_N}{M_N}}$$

where

m_{total} is total mass of rare earth elements, in g;

n_{total} is total number of moles of rare earth elements, in moles;

m_i is mass of rare earth element i , $i = 1, 2, \dots, N$, in g;

M_i is atomic mass of rare earth element i , $i = 1, 2, \dots, N$, in g/mol.

Note 1 to entry: $\bar{M}$ is given in g/mol.

EXAMPLE 1 The average atomic mass of a *mixed rare earth metal* (4.4) containing 20 % mass of praseodymium and 80 % of neodymium is calculated as follows:

$m_{\text{Pr}} = 20$ units, $m_{\text{Nd}} = 80$ units, $M_{\text{Pr}} = 140,907,7$ g/mol, $M_{\text{Nd}} = 144,24$ g/mol

$$\bar{M} = \frac{\frac{20}{140,907,7} + \frac{80}{144,24}}{\frac{20}{140,907,7} + \frac{80}{144,24}} = 143,56$$

EXAMPLE 2 The average atomic mass of rare earths in *Tb-Dy-Fe* (5.21) magnetostrictive materials, of which the formula is $\text{Tb}_{0,3}\text{Dy}_{0,7}\text{Fe}_2$, is calculated as follows:

$M_{\text{Tb}} = 158,9254$ g/mol, $M_{\text{Dy}} = 162,5$ g/mol, $M_{\text{Fe}} = 55,847$ g/mol

$m_{\text{Tb}} = M_{\text{Tb}} \times 0,3 / (M_{\text{Tb}} \times 0,3 + M_{\text{Dy}} \times 0,7 + M_{\text{Fe}} \times 2) \times 100 = 17,46$ units

$m_{\text{Dy}} = M_{\text{Dy}} \times 0,7 / (M_{\text{Tb}} \times 0,3 + M_{\text{Dy}} \times 0,7 + M_{\text{Fe}} \times 2) \times 100 = 41,65$ units

$$\bar{M} = \frac{\frac{17,46}{158,9254} + \frac{41,65}{162,5}}{\frac{17,46}{158,9254} + \frac{41,65}{162,5}} = 161,43$$

3.6

rare earth metal purity

absolute rare earth metal purity

mass fraction of a specified rare earth element in a metal

Note 1 to entry: It is expressed as a percentage.

3.7

relative rare earth metal purity

mass fraction of the specified rare earth element out of the *rare earth metal content* (3.4)

Note 1 to entry: It is expressed as a percentage, i.e. Nd/TREM.

4 Terms related to rare earth metals

4.1

rare earth metal

metallic substance containing one or more rare earth elements

4.2

individual rare earth metal

metallic substance containing only one rare earth element, including La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Sc and Y

Note 1 to entry: The basic information for each rare earth element is given in ISO 22444-1:2020, Table A.1. The basic properties of *rare earth metals* (4.1) are given in [Table A.1](#).

4.3

high purity rare earth metal

individual rare earth metal (4.2) with a minimum *rare earth metal purity* (3.6) of 99,9 %

Note 1 to entry: The main impurities to be controlled typically include *rare earth impurities* (3.1), Si, K, Na, Ca, Mg, Al, Ti, Ni, Co, Mn, Cu, Fe, Pb, Zn, Sn, Cd, Ta, Nb, Cr, W, Mo, C, S, P, Cl, F, N and O.

4.4

mixed rare earth metal

metallic substance containing two or more rare earth elements

4.5

mischmetal

metallic substance mainly containing the rare earth elements Ce and La as major components, with small amounts of Nd, Pr, etc., of which the compositional ratio of each REE is typically similar to that found in the resource minerals

4.6

Pr-Nd metal

didymium

metallic substance containing the rare earth elements of Pr and Nd

Note 1 to entry: It is occasionally represented by the abbreviation Di.

Note 2 to entry: The content of Pr in Di is generally more than 18 %.

4.7

La-Ce metal

metallic substance containing the rare earth elements of La and Ce

5 Terms related to rare earth alloys

5.1

rare earth alloy

metallic substance containing one or more rare earth elements and one or more non-rare earth metal(s) or semi-metal element(s)

Note 1 to entry: The alloys may be compounds, solid solutions, intermetallics or mixtures of the components.

5.2

rare earth master alloy

rare earth alloy (5.1) of selected rare earth element(s) that can be added to a charge of molten metal to provide a desired composition or texture or to deoxidize the material

Note 1 to entry: The content of rare earth element(s) in rare earth master alloy is generally higher than that in the *rare earth modified alloy* (5.10).

5.3

rare earth ferroalloy

alloy containing Fe and one or more rare earth elements

Note 1 to entry: The main rare earth ferroalloys are Dy-Fe, Gd-Fe, Ce-Fe and Ho-Fe alloy.

5.4

rare earth ferrosilicon alloy

ferroalloy typically containing approximately 35 % to 50 % Si by mass with the remainder being Fe and one or more rare earth elements

Note 1 to entry: Other elements such as Mg, Al, Mn and Ca are often also present.

5.5

rare earth magnesium ferrosilicon alloy

ferroalloy mainly containing Si, Fe, Mg and one or more rare earth elements

Note 1 to entry: Other elements such as Al, Mn, Ca and Ti are often also present.

5.6

rare earth aluminium alloy

alloy containing Al and one or more rare earth elements

Note 1 to entry: Rare earth aluminium alloy can be used as additive. The main rare earth aluminium alloys are Y-Al, Sc-Al, Gd-Al, Er-Al and La-Al alloy.

Note 2 to entry: Rare earth aluminium alloy can be also used as target material, such as Sc-Al alloy.

5.7

rare earth magnesium master alloy

alloy containing Mg and one or more rare earth elements

Note 1 to entry: The main rare earth magnesium alloys are Nd-Mg, Y-Mg, Gd-Mg, Ce-Mg and La-Mg alloy.

5.8

rare earth copper master alloy

alloy containing Cu and one or more rare earth elements

Note 1 to entry: The main rare earth copper alloys are La-Cu and Ho-Cu alloy.

5.9

rare earth nickel master alloy

alloy containing Ni and one or more rare earth elements

Note 1 to entry: The typical rare earth-nickel alloy is *La-Ni* (5.18) alloy.

5.10

rare earth modified alloy

alloy typically containing a small portion of rare earth element(s) that are added intentionally to modify its properties

5.11

rare earth modified aluminium alloy

alloy mainly containing a large amount of Al, a small portion of rare earth element(s) and other alloying element(s) that are added intentionally to modify its properties

Note 1 to entry: The main additive rare earth elements are Sc, Y, Er, Gd, La, Ce, Sm, etc.

5.12**rare earth modified magnesium alloy**

alloy mainly containing a large amount of Mg, a small portion of rare earth element(s) and other alloying element(s) that are added intentionally to modify its properties

Note 1 to entry: The main additive rare earth elements are Y, La, Ce, Nd, Gd, etc.

5.13**rare earth modified copper alloy**

alloy mainly containing a large amount of Cu, a small portion of rare earth element(s) and other alloying element(s) that are added intentionally to modify its properties

Note 1 to entry: The main additive rare earth elements are Y, La, Ce, Pr, Sm, etc.

5.14**rare earth modified titanium alloy**

alloy mainly containing a large amount of Ti, a small portion of rare earth element(s) and other alloying element(s) that are added intentionally to modify its properties

Note 1 to entry: The main additive rare earth elements are La, Ce, Er, Y, Gd, Nd, etc.

5.15**rare earth intermetallic compound**

intermetallic compound composed of rare earth element(s) and other metallic element(s) and/or semi-metal element(s), bonded with specific stoichiometries by mixed metallic, covalent and ionic bonding

5.16**Nd-Fe-B**

rare earth intermetallic compound (5.15) composed of Nd, Fe and B, with a typical chemical formula of $\text{Nd}_2\text{Fe}_{14}\text{B}$

Note 1 to entry: Nd may be partially substituted with Ce, Pr, etc.

5.17**Ce-Fe-B**

rare earth intermetallic compound (5.15) composed of Ce, Fe and B, with a typical chemical formula of $\text{Ce}_2\text{Fe}_{14}\text{B}$

5.18**La-Ni**

rare earth intermetallic compound (5.15) composed of La and Ni, with typical chemical formulae of LaNi_5 and La_2Ni_3

Note 1 to entry: La may be partially substituted with Ce.

5.19**Sm-Co**

rare earth intermetallic compound (5.15) composed of Sm and Co, with typical chemical formulae of SmCo_5 and $\text{Sm}_2\text{Co}_{17}$

Note 1 to entry: In the latter compound, Co may be partially substituted with Fe, Cu, Zr, etc.

5.20**Gd-Si-Ge**

intermetallic compound composed of Gd, Si and Ge, with a typical chemical formula of $\text{Gd}_5(\text{Si,Ge})_4$

5.21**Tb-Dy-Fe**

intermetallic compound composed of Tb, Dy and Fe, with a typical chemical formula of $(\text{TbDy})\text{Fe}_2$

5.22

Sm-Fe-N

intermetallic compound composed of Sm, Fe and N, with typical chemical formulae of $\text{Sm}_2\text{Fe}_7\text{N}_x$ and SmFe_7N_x

5.23

La-Fe-Si

intermetallic compound composed of La, Fe and Si, with a typical chemical formula of $\text{La}(\text{Fe}, \text{Si})_{13}$

Note 1 to entry: La may be partially substituted with Ce and Pr, and Fe may also be partially substituted with Co.

6 Terms related to the preparation and purification process of rare earth metals and their alloys

6.1

metallothermic reduction

method for preparing a metal or alloy by reducing the metal from its compound with another chemically active metal

Note 1 to entry: Commonly used reducing agents include Li, Na, Ca, Mg and Al. This method is used to prepare *individual rare earth metals* (4.2), *mixed rare earth metals* (4.4) and *rare earth master alloys* (5.2).

6.2

silicothermic reduction

ferrosilicon reduction process

method for producing *rare earth ferrosilicon alloys* (5.4) or other *rare earth master alloys* (5.2) from rare earth oxides, rare earth enriched slag or rare earth concentrate by reduction with silicon or ferrosilicon

6.3

carbothermic reduction

method for producing *rare earth ferrosilicon alloys* (5.4) from rare earth oxides, rare earth enriched slag or rare earth concentrate slag by reduction with coke

6.4

reduction-distillation method

method for producing higher vapour pressure *rare earth metals* (4.1) (e.g. Sm) using a metal with a lower vapour pressure (such as La) to reduce the oxides of target metals, the metal product evaporating into the gas phase, and then transferring and being collected at the condensing zone

Note 1 to entry: This method is used to prepare *individual rare earth metals* (4.2) of Sm, Eu, etc.

6.5

intermediate alloy method

method for producing *individual rare earth metals* (4.2) by the *vacuum distillation* (6.11) of a low melting point intermediate alloy, which is prepared using high-melting-point rare earth fluoride reduced by calcium thermal reduction, with other low melting-point and high-vapour-pressure metal(s) (such as Mg and Zn) at a low temperature

Note 1 to entry: This method is used to prepare individual rare earth metals of Gd, Tb, etc.

6.6

molten salt electrolysis

process involving the passage of an electric current through a molten-salt electrolyte with the subsequent migration of positively and negatively charged ions to the negative and positive electrodes, respectively

Note 1 to entry: Rare earth ions gain electrons to become neutral atoms, with the newly formed rare earth atoms depositing onto the cathode.

Note 2 to entry: This method is used to prepare La, Ce, *Pr-Nd metal* (4.6), Dy-Fe alloy, etc.

6.7**reduction-diffusion method****R-D method**

method for preparing *rare earth alloys* (5.1) by thermal diffusion between a *rare earth metal* (4.1) and the added cobalt, iron or other transition metals, in which the rare earth metal is reduced from its oxide (mainly used with Sm, Nd and Pr oxides) by calcium metal

Note 1 to entry: The rare earth alloys include *Sm-Co* (5.19), *Sm-Fe* and *Nd-Fe-B* (5.16) alloys.

6.8**co-reduction method**

method for preparing *rare earth alloys* (5.1) through the simultaneous reduction of a mixture of oxides of the alloying element(s) and rare earth oxide by Ca metal

Note 1 to entry: This method is mainly used to prepare *Sm-Co* (5.19) alloys.

6.9**mixed smelting**

method for producing *rare earth alloys* (5.1) through smelting and uniform mixing of one or more rare earth elements and other alloying element(s) simultaneously, with specific proportions

6.10**vacuum refining**

method for purifying *rare earth metals* (4.1) by volatilizing the volatile impurities at a temperature above the melting point of the rare earth metal under vacuum or negative pressure conditions

Note 1 to entry: It is used as the preliminary purification method for crude metal prepared by Ca thermal reduction or *molten salt electrolysis* (6.6), and is typically, but not exclusively, applied to La and Y.

6.11**vacuum distillation****sublimation**

purification method for separating *rare earth metals* (4.1) from impurities by heating rare earth metals under a vacuum, based on significant differences between the vapour pressure of the rare earth metal and the impurities

Note 1 to entry: This method is typically, but not exclusively, used to purify Sm, Dy and Tm.

6.12**electrorefining**

method for purifying *rare earth metals* (4.1) through the exploitation of differences in anodic dissolution and cathodic precipitation for different elements, in which rare earth metal is used as a soluble anode and dissolved, then the high-purity rare earth metal of the same element is deposited at the cathode with direct electric current passing by

6.13**solid state electrotransport**

method for purifying *rare earth metals* (4.1) by the ordered migration of impurity atoms to the two ends of an associated metal rod under the effect of direct electric field

Note 1 to entry: This method is typically, but not exclusively, used to purify La and Y.

6.14**zone refining**

method for purifying *rare earth metals* (4.1) in which a narrow molten zone is moved slowly along the complete length of the specimen, to bring about impurity segregation, and which is based on compositional differences of the liquid and solid in equilibrium

Note 1 to entry: This method is typically, but not exclusively, used to purify La and Y.

6.15

electron beam melting purification

method for purifying *rare earth metals* (4.1) by an electron beam under vacuum conditions, in a water-cooled Cu crucible

Note 1 to entry: This method is typically, but not exclusively, used to purify La and Y.

6.16

levitation melting

method for melting and purifying metals without being in contact with a supporting substrate, by using the Lorentz forces induced current provided by a high-frequency magnetic field that surrounds the vessel to suspend the melt

Note 1 to entry: This method is typically, but not exclusively, used to purify La and Y.

6.17

fused-salt extraction method

method for purifying metals by separating impurities from the valuable elements based on the partition coefficient differences of different elements in the molten metal and the slag

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