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Rare earth — Vocabulary —

Part 1: Minerals, oxides and other compounds

Terres rares — Vocabulaire —

Partie 1: Minéraux, oxydes et autres composants

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Foreword

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

A list of all parts in the ISO 22444 series can be found on the ISO website.

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Introduction

Rare earth elements are widely used. Different business and industry sectors have various descriptions for rare earth elements and their compounds and alloys. Therefore, it is of vital importance to unify the terminology used in the rare earth industry.

About 250 minerals contain significant amounts of rare earth elements although there are only a few that are economically exploited at this time. Various rare earth oxides and other compounds are obtained from these rare earth minerals as they are processed through to intermediate products and on to final products.

This document specifies terms for use by producers, consumers and traders in the field of rare earth minerals, oxides and other compounds. 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 minerals, oxides and other compounds.

Rare earth — Vocabulary —

Part 1:
Minerals, oxides and other compounds

1 Scope

The document defines the terms for rare earth minerals, oxides and other compounds, as well as for related production processes.

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 element
collective name for scandium (Sc), yttrium (Y) and the lanthanides (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu), which was approved by the International Union for Pure and Applied Chemistry (IUPAC) in its 2005 Nomenclature of Inorganic Chemistry Recommendations[1]

Note 1 to entry: Certain terms and corresponding abbreviated terms are common such as rare earth element (REE or RE) and *rare earth oxide (REO)* (5.2.1).

Note 2 to entry: Rare earth elements are frequently referred to as being either light rare earth (LREE), medium rare earth (MREE) or heavy rare earth (HREE), with LREE including the elements between lanthanum (La) and neodymium (Nd), MREE including the elements between samarium (Sm) and gadolinium (Gd), and HREE including the elements from terbium (Tb) to lutetium (Lu) as well as scandium (Sc) and yttrium (Y).

Note 3 to entry: Didymium is commonly used to express a mixture of the elements Pr and Nd.

Note 4 to entry: Characteristics of rare earth elements are described in Annex A.

3.2
rare earth mineral
mineral containing one or more *rare earth elements* (3.1)

Note 1 to entry: Rare earths can be present as a simple compound, incorporated in the lattice of another mineral, or sorbed to another mineral, such as *bastnaesite* (4.1.1), *monazite* (4.1.2) or montmorillonite as in ionic clay deposits.

3.3
rare earth ore
rare earth mineralization found in nature in various types of ore deposit

Note 1 to entry: Those deposit types that are now, or have previously been, commercially exploited include *Baiyun Obo ore* (4.2.1), *ion-adsorption rare earth ore* (4.2.2), *carbonatite/alkalic pipe* (4.2.3), *weathered carbonatite* (4.2.4) and *beach sand* (4.2.5).

3.4
rare earth deposit
area or volume of the earth's crust where there is an accumulation of *rare earth minerals* (3.2), with or without other valuable minerals, that is of economic interest

3.5
rare earth grade
mass fraction of *rare earth oxide (REO)* (5.2.1) in the deposit/concentrate or tailings

Note 1 to entry: The grade can be present as a percentage or as either kg/t or g/t. Statements of grade shall clearly state if the data are given on a REE, RE or REO basis.

Note 2 to entry: When a rare earth metal mass is converted to oxide mass, all *rare earth elements (REEs)* (3.1) should be taken as trivalent except for the following oxide forms: ceric oxide, CeO_2, praseodymium oxide, Pr_6O_{11}, and terbium oxide, Tb_4O_7.

3.6
rare earth mineral resource and mineral reserve
resources of ore or minerals containing rare earths, which can be mined legally and profitably under existing conditions

Note 1 to entry: Indicated reserve is the estimate of ore computed from boreholes, outcrops and developmental data, and is projected for a reasonable distance on geologic evidence.

3.7
rare earth content
total rare earth content
mass fraction of rare earths in the material

Note 1 to entry: For *rare earth oxides* (5.2.1) and other compounds, the fraction is generally provided as a percentage of rare earth oxide, i.e. % REO or % TREO. For metals and alloys, the content is generally provided as a percentage of rare earth metal, i.e. % REM or % TREM.

3.8
rare earth distribution
mass fraction of each individual rare earth in a material containing a mixture of rare earths compared to the *rare earth content* (3.7) of the material

Note 1 to entry: The distribution is normally expressed as the percentage of rare earth metal, i.e. % RE or % REM for metals and alloys, and percentage of *rare earth oxide* (5.2.1), i.e. % REO, for compounds and other materials.

3.9
average molar mass of mixed rare earth compounds
$\bar{M}$
ratio of the total mass of all rare earth compounds to their total number of moles, as shown by the formula:

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

where

m_{total} is the total mass of mixed rare earths, in g;

n_{total} is the total number of moles of mixed rare earths, in moles;

m_i is the mass of rare earth compound *i*, *i* = 1, 2, ..., *N*, in g;

M_i is the molar mass of rare earth compound *i*, *i* = 1, 2, ..., *N*. The basic unit of calculation is $1/x(RE_xB_y)$, in g/mol.

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

EXAMPLE 1 The average molar mass of a mixed *rare earth oxide* (5.2.1) containing 40 % mass of lanthanum oxide and 60 % of yttrium oxide is calculated as follows:

m_{La2O3} = 40 units, m_{Y2O3} = 60 units, M_{La} = 325,81/2 = 162,90 g/mol, M_Y = 225,81/2 = 112,90 g/mol

$$\bar{M} = \frac{40+60}{\frac{40}{162,9}+\frac{60}{112,9}} = 128,7\ \text{g/mol}$$

EXAMPLE 2 The average molar mass of a mixed *rare earth oxide* (5.2.1) containing 25 % of praseodymium oxide and 75 % of neodymium oxide is calculated as follows:

m_{Pr6O11} = 25 units, m_{Nd2O3} = 75 units, M_{Pr} = 1 021,44/6 = 170,24 g/mol, M_{Nd} = 336,48/2 = 168,24 g/mol

$$\bar{M} = \frac{25+75}{\frac{25}{170,2}+\frac{75}{168,2}} = 168,7\ \text{g/mol}$$

EXAMPLE 3 The average molar mass of a mixed *rare earth chloride* (5.2.2) containing 40 % of lanthanum chloride and 60 % of cerium chloride is calculated as follows:

m_{LaCl3} = 40 units, m_{CeCl3} = 60 units, M_{LaCl3} = 245,26 g/mol, M_{CeCl3} = 246,48 g/mol

$$\bar{M} = \frac{40+60}{\frac{40}{245,26}+\frac{60}{246,48}} = 246,0\ \text{g/mol}$$

3.10
rare earth impurity
undesirable *rare earth element* (3.1), apart from the target rare earth component(s) in a rare earth product

3.11
non-rare earth impurity
undesirable non-rare earth component in a rare earth product

EXAMPLE Fe, Al, Ca, SO_4^{2-}.

3.12
rare earth purity
absolute rare earth purity
mass fraction of a specified *rare earth element* (3.1) or *rare earth oxide* (5.2.1) in a rare earth product

Note 1 to entry: It is expressed as a percentage and with the basis (REM or REO) stated.

Note 2 to entry: The content of target element in the oxide, metal or compound is expressed by purity when the content is higher than 90 %.

3.13
relative rare earth purity
mass fraction of the specified *rare earth element* (3.1) or *rare earth oxide* (5.2.1) out of the *rare earth content* (3.7)

Note 1 to entry: It is expressed as a percentage and with the basis (REM or REO) stated.

4 Terms related to rare earth minerals and ore

4.1 Rare earth minerals

4.1.1
bastnaesite
yellow, reddish brown, light green or brown carbonate-fluoride mineral, usually containing 65 % to 75 % *rare earth oxide* (5.2.1), with the formula of (Ce,La,Nd,Pr) CO_3F

Note 1 to entry: The family of carbonate-fluoride minerals includes bastnaesite-(Ce) with a formula of (Ce,La) CO_3F, bastnaesite-(La) with a formula of (La,Ce)CO_3F, and bastnaesite-(Y) with a formula of (Y,Ce)CO_3F. Most of the mineral is bastnaesite-(Ce), and cerium is by far the most common of the rare earths in this class of minerals.

Note 2 to entry: The Mohs hardness of the mineral is 4 to 4,5, and the density is generally 4 700 kg/m^3 to 5 100 kg/m^3.

Note 3 to entry: The mineral is soluble in HCl, H_2SO_4, HNO_3 and H_3PO_4.

4.1.2
monazite
yellow-brown, brown, red and sometimes green mineral, usually containing 55 % to 70 % of *rare earth oxide* (5.2.1), with the formula of (Ce,La,Nd,Pr,Th)PO_4

Note 1 to entry: The mineral is usually found in small free crystals, and the mineral composition is mostly light rare earth. The presence of thorium can create radioactivity issues.

Note 2 to entry: The Mohs hardness of the mineral is 5,05 to 5,5, and the density is generally 4 900 kg/m^3 to 5 500 kg/m^3.

Note 3 to entry: The mineral is soluble in H_3PO_4, H_2SO_4 and $HClO_4$ depending on composition and pre-treatment processes.

4.1.3
xenotime
yellow, brown and sometimes yellowish green *rare earth phosphate* (5.2.9) mineral, typically containing 50 % to 65 % *rare earth oxide* (5.2.1), which is generally yttrium phosphate (YPO_4)

Note 1 to entry: Besides yttrium, the mineral often contains other heavy *rare earth elements* (3.1) such as dysprosium, erbium, terbium and ytterbium. The presence of thorium can create radioactivity issues. The mineral is a significant source of yttrium and heavy rare earth metals.

Note 2 to entry: The Mohs hardness of the mineral is 4 to 5 and the density is generally 4 400 kg/m^3 to 5 100 kg/m^3.

4.1.4
fergusonite
typically yellow, tawny or black complex mineral, typically containing 43 % to 53 % *rare earth oxide* (5.2.1), with the chemical formula of (Y,REE) NbO_4

Note 1 to entry: Usually, the main rare earth in the mineral is yttrium, but sometimes cerium, lanthanum and neodymium can be substituted.

Note 2 to entry: The Mohs hardness of the mineral is 5,5 to 6,5 and the density is generally 4 900 kg/m^3 to 5 800 kg/m^3.

Note 3 to entry: The mineral is partially dissolved in HCl and dissolved in H_2SO_4, H_3PO_4 and HF depending on composition and pre-treatment processes.

4.1.5
loparite
black, ash black or streak reddish brown mineral, typically containing 30 % to 40 % *rare earth oxide* (5.2.1), with a general chemical formula of $(Na,Ce,Ca,La,Sr)O_3(Ti,Nb)$

Note 1 to entry: The Mohs hardness is 5,6 to 6,0 and the density is generally 4 600 kg/m^3 to 4 900 kg/m^3.

Note 2 to entry: If the Nb_2O_3 is greater than 25 %, it is called niobium-rich loparite.

Note 3 to entry: The mineral is generally not soluble in acids except for hydrofluoric acid.

4.2 Rare earth ores and concentrate

4.2.1
Baiyun Obo ore
mixed *rare earth ore* (3.3) containing *rare earth elements* (3.1) in *bastnaesite* (4.1.1) and *monazite* (4.1.2) and iron as magnetite and hematite

Note 1 to entry: It is named after Baiyun Obo in Inner Mongolia where the ore is processed for the production of *rare earth concentrate* (4.2.6) and iron concentrates.

4.2.2
ion-adsorption rare earth ore
clay minerals, such as montmorillonite, that have sorbed rare earth ions released by intense weathering of primary *rare earth minerals* (3.2) through ion exchange mechanisms, also known as weathered crust elution-deposited *rare earth ore* (3.3)

Note 1 to entry: The ore is a major source of heavy rare earths and is found in various parts of the world, generally in the tropics.

4.2.3
carbonatite/alkalic pipe
rare earth deposits (3.4) hosted by carbonatite/alkalic pipes and overlying alkali volcanic deposits

Note 1 to entry: The rare earth mineralization is often in the form of *bastnaesite* (4.1.1) although *monazite* (4.1.2) is also frequently encountered. Gangue minerals are usually carbonates.

EXAMPLE Mountain Pass in the USA, Kvanefjeld in Greenland.

4.2.4
weathered carbonatite
carbonatites having experienced intensive weathering and leaching processes that have, in many cases, led to enrichment of the rare earths

EXAMPLE Mt. Weld deposit in Australia, the Tomtor deposit in Russia.

4.2.5
beach sand
rare earth minerals (3.2) that generally have high specific gravities and can be concentrated by the action of flowing water in coastal or riverine heavy mineral deposits

Note 1 to entry: Such deposits are common in Australia, India and Southern Africa.