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矿物 矿石 宝石 岩石 陨石

François Cardarelli

Materials Handbook

A Concise Desktop Reference

Second Edition

哈爾濱工業大學出版社
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by François Cardarelli

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《材料手册》(8册)是 Springer ***Materials Handbook*** *A Concise Desktop Reference* (2nd Edition)的影印版。为使用方便，由原版1卷分为8册：

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本手册提供各种材料的物理和化学性质，是一本简洁的手边工具书。第二版与第一版的差别是扩充了新的家用材料，但重点是每一类常见的工业材料。

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François Cardarelli

Materials Handbook

A Concise Desktop Reference

2nd Edition

Springer

Dedication for the First Edition

The ***Materials Handbook*: *A Concise Desktop Reference*** is dedicated to my father, Antonio, and my mother, Claudine, to my sister, Elsa, and to my spouse Louise Saint-Amour for their love and support. I want also to express my thanks to my two parents and my uncle Consalvo Cardarelli, which in close collaboration have provided valuable financial support when I was a teenager to contribute to my first fully equipped geological and chemical laboratory and to my personal comprehensive scientific library. This was the starting point of my strong and extensive interest in both science and technology, and excessive consumption of scientific and technical literature.

François Cardarelli

Dedication for the Second Edition

The ***Materials Handbook: A Concise Desktop Reference*** is dedicated to my father, Antonio, and my mother, Claudine, to my sister, Elsa, and to my wife Elizabeth I.R. Cardarelli for their love and support. I want also to express my thanks to my two parents and my uncle Consalvo Cardarelli, which in close collaboration have provided valuable financial support when I was a teenager to contribute to my first fully equipped geological and chemical laboratory and to my personal comprehensive scientific library. This was the starting point of my strong and extensive interest in both science and technology, and excessive consumption of scientific and technical literature.

François Cardarelli

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Mr. Anthony Doyle (senior engineering editor), Mr. Oliver Jackson (associate engineering editor), and Mr. Nicolas Wilson (editorial coordinator) are gratefully acknowledged for their valued assistance, patience, and advice.

Units Policy

In this book the only units of measure used for describing physical quantities and properties of materials are those recommended by the *Système International d'Unités* (SI). For accurate conversion factors between these units and the other non-SI units (e.g., cgs, fps, Imperial, and US customary), please refer to the reference book by the same author:

Cardarelli, F. (2005) *Encyclopaedia of Scientific Units, Weights, and Measures. Their SI Equivalences and Origins*. Springer, London New York. ISBN 978-1-85233-682-1.

Author Biography

Dr. François Cardarelli (Ph.D.)
Born in Paris (France) February 17, 1966
Canadian citizen

Academic Background

- Ph.D., chemical engineering (Université Paul Sabatier, Toulouse, France, 1996)
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- DEST credits in nuclear sciences and technologies (Conservatoire National des Arts et Métiers, Paris, 1988)

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(1) Research scientist at the Laboratory of Electrochemistry (Université Pierre & Marie Curie, Paris, France) for the development of a nuclear detector device for electrochemical experiments involving radiolabeled compounds;

(2) research scientist at the Institute of Marine Biogeochemistry (CNRS & École Normale Supérieure, Paris, France) for the environmental monitoring of heavy-metal pollution by electroanalytical techniques;

(3) research scientist for the preparation by electrochemistry in molten salts of tantalum protective thin coatings for the chemical-process industries (sponsored by Electricité de France);

(4) research scientist for the preparation and characterization of iridium-based industrial electrodes for oxygen evolution in acidic media at the Laboratory of Electrochemical Engineering (Université Paul Sabatier, Toulouse, France);

(5) registered consultant in chemical and electrochemical engineering (Toulouse, France);

(6) battery product leader in the technology department of ARGOTECH Productions, Boucherville (Québec), Canada, in charge of electric-vehicle, stationary, and oil-drilling applications of lithium polymer batteries;

(7) materials expert and industrial electrochemist in the lithium department of ARGOTECH Productions, involved in both the metallurgy and processing of lithium metal anodes and the recycling of spent lithium polymer batteries;

(8) materials expert and industrial electrochemist in the technology department of AVESTOR, Boucherville (Quebec), Canada, in charge of all strategic raw materials entering into the fabrication of lithium polymer batteries, as well as being in charge of the recycling process of spent lithium batteries;

(9) principal chemist, materials, in the technology department of RIO TINTO Iron and Titanium, Sorel–Tracy (Québec), Canada working on the electrowinning of titanium metal from titania-rich slags and on other novel electrochemical processes;

(10) principal electrochemist at Materials and Electrochemical Research (MER) Corp., Tuscon (Arizona, USA) working on the electrowinning of titanium metal powder from composite anodes and other materials related projects.

Introduction

Despite the wide availability of several comprehensive series in materials sciences and metallurgy, it is difficult to find grouped properties either on metals and alloys, traditional and advanced ceramics, refractories, polymers and elastomers, composites, minerals and rocks, soils, woods, cement, and building materials in a single-volume source book.

Actually, the purpose of this practical and concise reference book is to provide key scientific and technical materials properties and data to materials scientists, metallurgists, engineers, chemists, and physicists as well as to professors, technicians, and students working in a broad range of scientific and technical fields.

The classes of materials described in this handbook are as follows:

(i) metals and their alloys;
(ii) semiconductors;
(iii) superconductors;
(iv) magnetic materials;
(v) dielectrics and insulators;
(vi) miscellaneous electrical materials (e.g., resistors, thermocouples, and industrial electrode materials);
(vii) ceramics, refractories, and glasses;
(viii) polymers and elastomers;
(ix) minerals, ores, and gemstones;
(x) rocks and meteorites;
(xi) soils and fertilizers;
(xii) timbers and woods;
(xiii) cement and concrete;
(xiv) building materials;
(xv) fuels, propellants, and explosives;

(xvi) composites;
(xvii) gases;
(xviii) liquids.

Particular emphasis is placed on the properties of the most common industrial materials in each class. The physical and chemical properties usually listed for each material are as follows:

(i) physical (e.g., density, viscosity, surface tension);
(ii) mechanical (e.g., elastic moduli, Poisson's ratio, yield and tensile strength, hardness, fracture toughness);
(iii) thermal (e.g., melting and boiling point, thermal conductivity, specific heat capacity, coefficients of thermal expansion, spectral emissivities);
(iv) electrical (e.g., resistivity, relative permittivity, loss tangent factor);
(v) magnetic (e.g., magnetization, permeability, retentivity, coercivity, Hall constant);
(vi) optical (e.g., refractive indices, reflective index, dispersion, transmittance);
(vii) electrochemical (e.g., Nernst standard electrode potential, Tafel slopes, specific capacity, overpotential);
(viii) miscellaneous (e.g., relative abundances, electron work function, thermal neutron cross section, Richardson constant, activity, corrosion rate, flammability limits).

Finally, detailed appendices provide additional information (e.g., properties of the pure chemical elements, thermochemical data, crystallographic calculations, radioactivity calculations, prices of metals, industrial minerals and commodities), and an extensive bibliography completes this comprehensive guide. The comprehensive index and handy format of the book enable the reader to locate and extract the relevant information quickly and easily. Charts and tables are all referenced, and tabs are used to denote the different sections of the book. It must be emphasized that the information presented here is taken from several scientific and technical sources and has been meticulously checked and every care has been taken to select the most reliable data.

Contents

12 Minerals, Ores and Gemstones

12.1 Definitions

In this section the main definitions, properties of minerals are detailed and explained.

Crystal. A crystal is a homogeneous solid with an ordered atomic space lattice which has developed a crystalline morphology when external crystallographic planes have had the possibility to grow freely without external constraints and under favorable conditions. Moreover, it is a chemical substance with a definite theoretical chemical formula. Nevertheless, the theoretical chemical composition is usually variable within a limited range owing to the isomorphic substitutions (i.e., diadochy), or/and low presence of traces of impurities.

Minerals. A mineral is defined as a naturally occurring, inorganic, and homogeneous crystal that has been formed as a result of geological processes with a definite but generally not fixed chemical composition. Therefore, minerals are the basic building entities of Earth's crust materials, i.e., rocks and soils. On the other hand, among the 4000 minerals species, the most abundant minerals found in common rocks (i.e., igneous, sedimentary, metamorphic and meteorites) are called by petrologists the ***rock forming minerals***.

Mineraloids. The mineraloids are naturally occurring substances having a structure which can be partially crystalline or noncrystalline, i.e., solids with an irregular atomic arrangement within the solid. For instance, compounds such as obsidian, opal, amber or succinite are defined as mineraloids.

Ores. An *ore* is a natural occurring mineral or association of minerals containing a high percentage of a metallic element, which form deposits from which this metal can be mined, extracted, and processed at a profit under favorable conditions. Therefore, it is

Table 12.1. Common gangue minerals

Class	Mineral
Oxides	Quartz
	Limonite
Carbonates	Calcite
	Dolomite
	Rhodocrosite
Sulfates	Baryte
	Gypsum
Halides	Fluorspar
Phosphates	Apatite
Silicates	Feldspars
	Clays
	Chlorites

economically defined. However, a distinction must be made between ore and ore minerals. A deposit of **ore minerals** in geological terms is not always an ore deposit, while an ore mineral is a mineral from which a metal can feasibly be extracted, and an **ore deposit** (or an **orebody**) is a mass of rock from which a metal or mineral can be profitably produced. What is, or is not, becomes dependent upon economic, technological, and political factors as well as geological criteria. A **protore** is a low-grade metalliferous material which is not in itself valuable but from which ore may be formed by superficial enrichment.

Gangue. The gangue is an earthy or nonmetallic mineral associated with the ore minerals of a deposit, i.e., a worthless material in which the ore mineral is disseminated and must be concentrated by classical ore beneficiation techniques (e.g., gravity separation, flotation, leaching). The most common gangue minerals are listed in Table 12.1.

Vein deposits. A ***vein*** is a mineral mass, more or less tabular, deposited by solutions in or along fracture of group of fractures. The ***country rock*** is the rock that encloses a metalliferous deposit. Vein ***walls*** are the rock surfaces on the borders of the veins. The ***footwall*** is the rock below an inclined vein, a bed, or a fault. The ***hanging wall*** is the rock above an inclined vein, bed or fault. A ***druse*** or ***vug*** is an unfilled portion of a vein usually lined with crystals. ***Gouge*** (*salbandes* in French) is a soft claylike material that occurs at some places as a selvage between a vein and country rock or in a vein.

Along with scientific and technical terms, prospectors, geologists and mining engineers have established various terms to describe and classify mineral resources. Some of these terms are defined hereafter based on standardized definitions introduced by the U.S. Geological Survey (USGS)[1].

Reserves. Amount of ore deposits economically recoverable at current prices using existing technologies. Because reserves include only recoverable materials, terms such as extractable or recoverable are redundant adjectives.

Marginal reserves. Part of the reserve base which, at the time of determination, borders on being economically producible.

1 U.S. Geological Survey Circular 831, 1980.

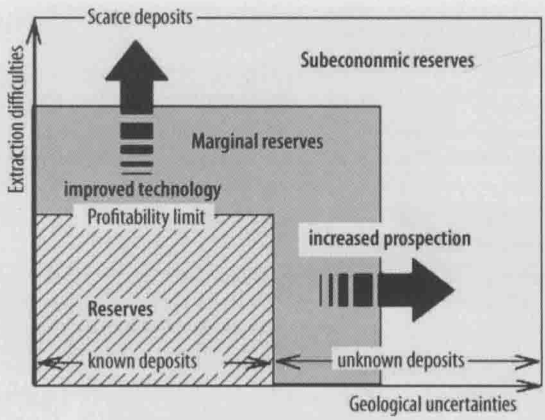

Figure 12.1. McKelvey diagram[2]

Subeconomic resources. Part of identified resources that does not meet the economic criteria of reserves and marginal reserves.

Reserve base. Part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those of grade, quality, thickness and depth. The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves) and finally those that are currently subeconomic (subeconomic resources).

Reserve base = Reserves + Marginal Reserves + Subeconomic Reserves

A schematic illustration of the economic viability of ore deposits based on the previous definitions is provided by the ***McKelvey diagram*** (see **Figure 12.1**).

Industrial minerals or nonmetallics. This designation includes all the minerals with economic importance, except those defined as ore, which are processed industrially. In fact, industrial minerals class also includes

(i) sedimentary rocks such as: limestone, dolomite, clays, sand, gravel, diatomite, and phosphates;
(ii) metamorphic rocks such as marble or slate; and
(iii) igneous rocks such as granite and basalt.

However in order to be rigorous from a mineralogical and petrological point of view it is preferable to split the previous group into two distinct subgroups:

(i) ***industrial minerals***, *sensu stricto*; and
(ii) ***industrial rocks***, *sensu stricto*.

A conventional listing of the more important nonmetallics is presented in Table 12.2.

Gemstones. A gemstone is a semi-precious or precious natural mineral with exceptional physical properties which, when cut and polished, can be used in jewelry. Only four minerals are considered as precious gemstones *sensu stricto*: ***diamond***, one gem variety of beryl (i.e., ***emerald***: green), and the two gem varieties of corundum (i.e., ***ruby***: deep red, and ***sapphire***: deep blue). Beside natural minerals synthetic gemstones and their simulants are also found in jewelry.

[2] McKelvey, V.E. – "Mineral Potential of the United States" in the Mineral Position of the United States 1975–2000 E.N. Cameron (Ed.) (1973) Univ. of Wisconsin Press, Madisson, Wi.

Table 12.2. Industrial minerals and rocks

Nonmetallics	Material	Industrial applications and uses
Industrial minerals s.s.	Asbestos (chrysotile, crocidolite, amosite, anthophyllite, tremolite, and actinolite)	(i) Spinning fibers: woven brake lining, clutch facing, fireproof and safety clothing, and blankets. (ii) Nonspinning fibers: roofing shingles, millboard, and corrugated panels for thermal insulation.
	Apatite (see also phosphate rock)	Fertilizers and chemical industry.
	Barite (baryte, heavyspar)	Oil-well drilling muds, filler in rubbers, paint extender, aggregate in speciality heavy weight concretes, flux in the glass industry, and barium chemicals
	Beryl and bertrandite	Beryllia, and beryllium chemicals
	Borax and borates (kernite, tincal, colemanite, and ulexite)	Fluxing agents in the manufacture of glass and vitreous enamel, borosilicated glasses (i.e., Pyrex®), borate fertlizers in agriculture, detergents and soaps, flame retardants, and in a lesser extent synthetic cubic boron nitride (i.e., Borazon®) for industrial abrasives, boron-doped semiconductors.
	Chalk	Aggregate
	Chromite (podiform and stratiform)	Only commercial source of chromium used in the metallurgical industry (85%) mainly as Fe–Cr for steelmaking, in the refractory and foundry market (8%) and in the chemical industry (7%).
	Cryolithe (cryolite)	Fluxing agent in the Hall–Heroult process in the aluminum industry.
	Diamond (bort varieties)	Abrasives, diamond drill in the mining industry, wire-drawing dies.
	Emery (corundum, magnetite, and spinel)	Abrasive for paper grit
	Feldspars (microcline, orthose, plagioclases)	Glass Industry for porcelain, enamels and glazes.
	Fluorspar (fluorite)	Foundry fluxes in steel making (metallurgical grade), preparation of hydrofluoric acid (acid grade), glass industry (ceramic grade).
	Garnets (pyrope, almandine, spessartine, uvarovite, grossular, spessartine)	Abrasives, blasting media, water jet cuttings, and water filtration.
	Graphite	Foundry molds facing (70%), crucibles, and lubricant.
	Gypsum and anhydrite	Gypsum wallboads for building purposes, fertilizers, sulfates and sulfuric acid.
	Kyanite	Refractories
	Magnesite	After calcination give periclase (MgO) used for refractories
	Manganese dioxide (psilomelane)	Primary batteries
	Micas (muscovite, phlogopite)	Electrical sheet insulators, furnaces windows, roofing materials.
	Nitrates (salpeter, niter, ammonium nitrate)	Fertilizers in agriculture, raw material for the chemical industry (i.e., pyrotechnics and explosives)