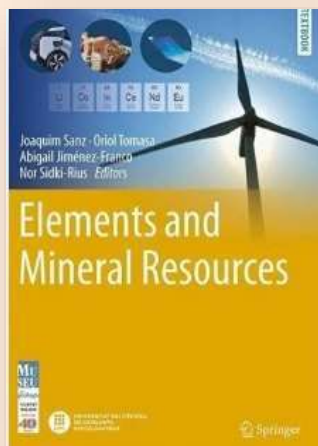




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ELEMENTS and MINERAL RESOURCES: uses and recycling (slides to project in class)

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Geological Museum Valentí Masachs (UPC)
2024**



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Talc

Tantalum

Tin

Titanium

Tungsten

Vanadium

Zeolites

Zinc

ALUMINIUM (Al) [Z=13] and *bauxite*



BAUXITE (rock formed from gibbsite, diaspore and boehmite)
mix of aluminium hydroxides and oxides
Miralles (Anoia) Catalonia

- The most abundant element in the Earth's crust.
- A good electrical conductor, malleable, ductile, soft and light.
- Provides a metal barrier that is impermeable to light, oxygen and bacteria.
- Obtained from bauxite. The EU considered it a strategic rock in 2020.
- **Main bauxite producing countries: Australia, Guinea, China (2023)(USGS)**
- **Main aluminium refining country: China 58% (2023)(USGS)**
- **The production of aluminium from recycled cans saves 95% electrical energy.**
- *Bauxite, as a rock, is used directly as an additive in cements, in the manufacture of fire bricks and as an abrasive.*
- *Scandium, a highly appreciated metal, can be found in the red mud obtained as a residue after the treatment of bauxite <http://www.redmud.org>.*

USES



Source: Market Research 2023


- transportation 40%
- packaging 25%
- construction 20%
- electrical/electronics 10%
- other 5%



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<https://www.usgs.gov/centers/national-minerals-information-center/aluminum-statistics-and-information>

ANTIMONY (Sb) [Z=51]

- A brittle metalloid with low hardness.
 - Low thermal and electrical conductivity.
 - Melts at low temperature (630°C) (with an lighter).
 - The EU classified antimony as a strategic metal in 2017.
 - Obtained from stibnite.
 - **Main producing countries: China 48%, Tajikistan 25%, Turkey 7% (2023)(USGS)**
 - **Main refining country: China 52% (2020)(SCREEN)**
-  This metal is recycled (28%) from exhausted lead batteries (SCREEN-UE) 2018



STIBNITE (antimony sulfide)
Abella (Ripollès) Catalonia

USES



- flame retardants 61%
- lead acid batteries 15%
- catalysts & alloys 14%
- ceramics & glass 7%
- others 3%

Source: Fortune Business Insights 2023



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GRAY, Theodore; MANN, Nick. *The elements*. New York,2009
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<http://www.eurometaux.eu> <http://www.antimony.com/>
<https://www.usgs.gov/centers/national-minerals-information-center/antimony-statistics-and-information>

BARITE

- A barium sulphate ($BaSO_4$)
- Has a high specific weight (4.5)
- Slightly soluble.
- Non-toxic, physically and chemically inert.
- Absorbs ionizing radiation and X rays (radiotherapy bunkers).
- **The EU classified *barite* as a strategic mineral in 2017.**
- **Main producing countries: India 32%, China 22%, Morocco 14% (2023)(USGS)**



Barite is recovered from well-drilling mud.

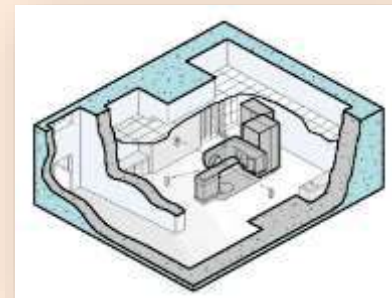


BARITE (barium sulphate)
Espinelves (Osona) Catalonia

USES



Source: Mordor Intelligence



REFERENCES AND LINKS

- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
- QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCH GmbH & Co, 2007
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- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <https://www.usgs.gov/centers/national-minerals-information-center/barite-statistics-and-information>
- <http://www.discoveriesinmedicine.com/Bar-Cod/Barium.html>

BERYLLIUM (Be) [Z=4]

- An alkaline earth metal, light and rare.
- Has a high melting point (1278°C) and a high heat capacity.
- High thermal conductivity, transparent to X-rays. Very toxic
- Obtained from bertrandite and beryl, and found in emerald and aquamarine.
- **The EU classified beryllium as a strategic metal in 2017.**
- **Main producing countries: EUA 57%, China 22%, Brazil 12% (2023)(USGS)**



A total of 10% of the beryllium that is consumed is recycled from scrap metal obtained from the manufacture of products with this metal.



BERYL (beryllium aluminosilicate)
Mina Assunção, Ferreira de Aves (Portugal)

USES



- electronics & telecom 30%
- industrial components 28%
- automotive 15%
- aerospace 15%
- oil and gas 10%
- others 2%

Source: Mordor Intelligence 2021




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- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
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- <http://eurometaux.eu> <https://www.beryllium.eu/>
<https://www.usgs.gov/centers/national-minerals-information-center/beryllium-statistics-and-information>

BORON (B) [Z=5] and *borates*

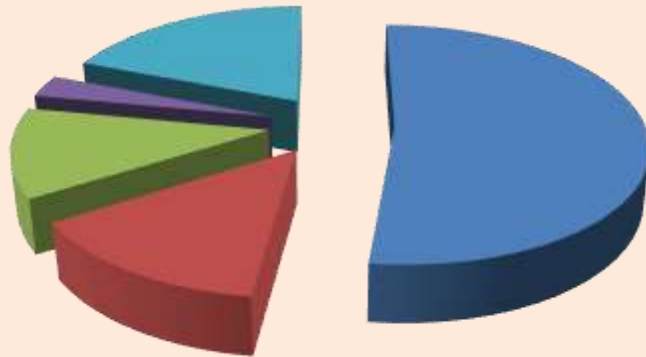
- A metalloid semiconductor.
- Very hard.
- Obtained from borax, ulexite, colemanite, and boron-rich brines.
- The EU classified boron and borates as a strategic minerals in 2017.
- **Main producing countries: Turkey, EUA, Chile, Bolivia (2023)(USGS)**

 Only insignificant quantities of boron (and borates) are recycled.



BORON-RICH BRINES
Salar de Uyuni (Bolivia)

USES



- glass 52%
- agriculture 14%
- ceramics 12%
- detergents 3%
- others 19%

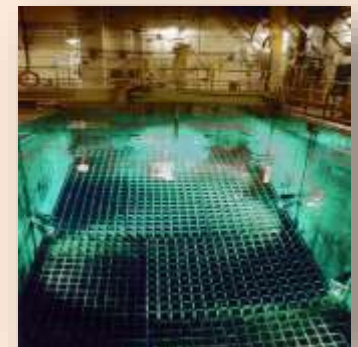


Source: Merchant Research 2023

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<https://www.usgs.gov/centers/national-minerals-information-center/boron-statistics-and-information>



CALCITE and *limestone*

- A calcium carbonate; brittle and not very hard.
- Reacts with acids and effervesces.
- A mineral that forms rocks such as limestones and marbles.



Calcium oxide (lime) is recycled in the paper industry, treatment plants and carbide production. Many marble quarries transform waste into gravel for gardens or use as a filler agent. Recycling or reuse of paper, plastics, helps reduce the consumption of limestone.



CALCITE (calcium carbonate)
Illes Medes (Baix Empordà) Catalonia

USES OF LIMESTONE



Source: IMA Europe



REFERENCES AND LINKS

GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
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<http://www.ima-europe.eu> http://www.reverteminerals.com/index_en.php

CHROMIUM (Cr) [Z=24]

- A very hard metal.
- Has a high melting temperature.
- Does not oxidise.
- Resistant to heat and friction.
- Can be very highly polished (mirrored surface).
- Obtained from chromite.
- Main producing countries: South Africa 44%, Turkey 15%, Kazakhstan 15% (2023)(USGS)
- Main refining countries: China and South Africa (2023)(USGS)
- In 2023, recycled chromium made up 26% of total chromium, and was obtained from the recycling of stainless steels that contain this metal (USGS)



CHROMITE (chromium oxide)
Turkey

USES



- stainless steel 40%
- electroplating and chemicals 30%
- refractory materials (chromite) 20%
- others 10%

Source: Market.us 2023

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GRAY, Theodore; MANN, Nick. *Els elements*. Barcelona: IEC/UAB/PUV, 2011
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<http://www.eurometaux.eu>
<https://www.usgs.gov/centers/national-minerals-information-center/chromium-statistics-and-information>



COBALT (Co) [Z=27]

- A metal with magnetic properties.
- High melting point (1500 °C).
- Heavy.
- **The EU considered that it was a strategic metal in 2017.**
- Obtained as a by-product of copper and nickel mining, from laterites rich in these metals, but also from cobalt hydroxides such as heterogenite.
- **Democratic Republic of Congo is the world's leading producer (73%) (2022)**
- **China is the world's leading refining (76%) (2022)**



It is estimated that 65% of recycled cobalt comes from battery recycling and 24% of hard metal recycling



HETEROGENITE (cobalt hydroxide)
Lubumbashi (DRC)

USES



Source: Cobalt Institute 2022

- EV batteries 40%
- portables batteries 30%
- super alloys 9%
- hard metals 5%
- catalysts 3%
- ceramics/colours 3%
- others 10%



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- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
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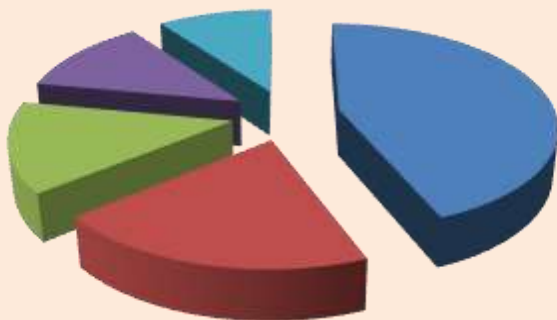
COOPER (Cu) [Z=29]

- A metal, a very good electrical and thermal conductor.
- Malleable, ductile and dense. Resistant to rusting.
- Has antimicrobial properties.
- Obtained from chalcopyrite, bornite, chalcocite and oxidised minerals such as brochantite and antlerite.
- The EU classified it as a strategic material in 2023.
- Main producing countries: Chile 23%, Peru 12%, RD. Congo 11% (2023)(USGS)
- Main refining countries: China 44%, Chile 7%, DR. Congo 7% (2023)(USGS)
- 100% recyclable, with no loss of quality.
- Recycling copper reduces SO₂ emissions by 86%, CO₂ emissions by 94%, and the generation of solid waste by 99%. Sixty per cent less energy is consumed, and 98% less water.



CHALCOPIRITE (cooper and iron sulfide)
El Brull (Osona) Catalonia

USES



- power grid 44%
- construction 20%
- electronics 14%
- transport 12%
- others 10%

Source: IWCC/ICA 2021

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<https://erocopper.com/> <http://www.coppercouncil.org/> <https://internationalcopper.org/>
<https://lafarga.es/en/copper/> <http://eurometaux.eu>
<https://www.usgs.gov/centers/national-minerals-information-center/copper-statistics-and-information>



FELDSPARS

These are potassium aluminium silicates: orthoclase (potassium feldspar), of sodium (albite) or calcium (anorthite).

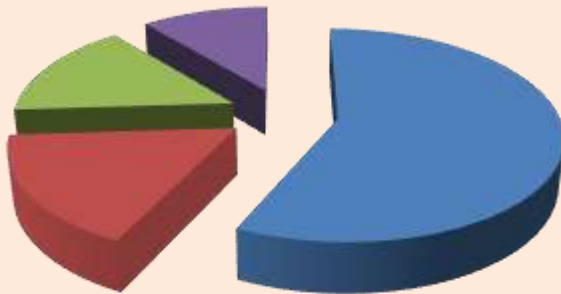
- Very hard (6 on the Mohs scale).
- Highly resistant to abrasion.
- Low viscosity.
- The EU classified it as a critical raw material in 2023.
- Main producing countries: Turkey 23%, India 19%, China 9% (2023)(USGS)

 Feldspars is not known to be recycled. However, the recycling of glass reduces the consumption of feldspars.



FELDSPAR (orthoclase) potassium aluminium silicate
Montnegre (Maresme) Catalonia

USES



- glass 57%
- ceramics 17%
- fillers 15%
- abrasives & others 11%

Source: Coherent Market Insights 2021



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SANZ et al., *Elements and Mineral Resources*. Springer Textbooks. Switzerland, 2022
<http://www.lansasa.com> <https://www.imerys.com/minerals/feldspar>
<https://www.usgs.gov/centers/national-minerals-information-center/feldspar-statistics-and-information>

FLUORINE (F) [Z=9] and *fluorite*

- Fluorine is a highly reactive, corrosive, toxic gas.
- It reacts with humid air and water to produce hydrofluoric acid (HF).
- It is the most electronegative element that is known.
- It is obtained from fluorite. In the EU it was considered a strategic mineral in 2017.
- Main fluorite producing countries: China 65%, Mexico 11%, Mongolia 11% (2023)(USGS)



- Fluorite is only recycled in very small amounts. Aluminium producers recycle the HF.
- The main uses of fluorite are in the extraction of hydrofluoric acid (HF), in the iron and aluminium foundry, and in the manufacture of glass as a fluidising agent.



FLUORITE (calcium fluoride)
Sant Cugat del Vallès (Vallès Occidental) Catalonia

USES (fluorite)



- hydrofluoric acid 48%
- steel foundry 27%
- aluminium foundry 18%
- glass/ceramic 4%
- others 3%

Source: Market.us 2023

REFERENCES AND LINKS

- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
- QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCH GmbH & Co, 2007
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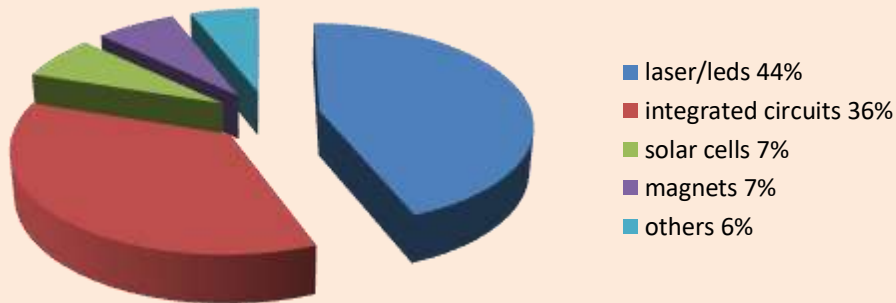
GALLIUM (Ga) [Z=31]

- A ductile, malleable metal.
- Liquid at a temperature of 30°C.
- A rare metal and a semiconductor.
- **The EU classified it as a strategic material in 2017.**
- Found in bauxite and sphalerite.
- **China is the world's main supplier of low purity gallium 98% (2024) (USGS)**
- Scrap metal generated in the manufacture of electronic components made with gallium arsenide can be recycled.



BAUXITE (aluminium hydroxides & oxides with gallium)
Fontespatlla (Matarranya)

USES



Source: Statista 2024




REFERENCES AND LINKS

- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
- QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCH GmbH & Co, 2007
- SANZ et al., *Elements and Mineral Resources*. Springer Textbooks. Switzerland, 2022
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <http://eurometaux.eu>
- <https://www.usgs.gov/centers/national-minerals-information-center/gallium-statistics-and-information>

GERMANIUM (Ge) [Z=32]

- A relatively rare metalloid semiconductor.
- Hard and brittle.
- Oxidises slowly in contact with air.
- **The EU classified it as a strategic metal in 2017.**
- Found in sphalerite.
- **Main producing country: China 94% (2023)(Investor News)**
- **Main refining country: China 59% (2023)(Investor News)**

 Approximately 30% of the germanium that is consumed worldwide is from recycled sources. In the process of manufacturing optical apparatus, over 60% of germanium is reused.



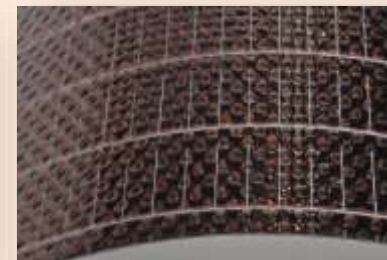
SPHALERITE (zinc sulfide with germanium)
Picos de Europa (Santander)

USES



Source: Merchant Research 2023

- fibre optics/lasers 34%
- infrared optics 22%
- polymerization catalysts 21%
- solar cells 17%
- others 6%




REFERENCES AND LINKS

GRAY, Theodore; MANN, Nick. *The elements*. New York,2009
 QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCH GmbH & Co,2007
 SANZ et al., *Elements and Mineral Resources*. Springer Textbooks. Switzerland, 2022
 STWERTKA, Albert, *A guide of the elements*,3rd ed. Oxford University Press, Inc.2012
<http://eurometaux.eu> <https://www.unicore.com/en/about/our-metals/germanium/>
<https://www.usgs.gov/centers/national-minerals-information-center/germanium-statistics-and-information>

GOLD (Au) [Z=79]

- A noble metal.
- This is the most ductile, malleable metal that is known.
- A very good reflector of heat and light.
- An excellent electrical conductor.
- Does not oxidise and is one of the most stable metals.
- Found in association with other minerals in primary deposits and alluvial deposits. In addition, it is obtained as a by-product of copper extraction.
- **Main producing countries: China 12%, Australia 10%, Russia 10%, Canada 7%, EUA 6%, Mexico 4%, Kazakhstan 4% (2023)(USGS)**

 A total of 100% is reusable and the maximum amount possible is recovered from jewellery and old electronic equipment.



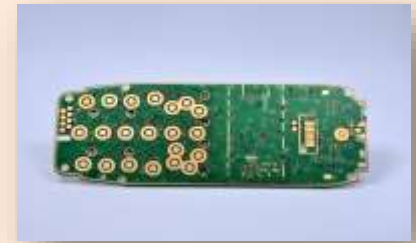
GOLD (native)
Nevada (USA)

USES



- jewellery 48%
- central banks 24%
- investment 21%
- technology 7%

Source: World Gold Council 2023



REFERENCES AND LINKS

- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
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- SANZ et al., *Elements and Mineral Resources*. Springer Textbooks. Switzerland, 2022
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- <https://www.gold.org/>
- <https://www.usgs.gov/centers/national-minerals-information-center/gold-statistics-and-information>



GRAPHITE (C) [Z=6]

- This is one of the allotropic forms of carbon.
- A soft material.
- A good solid lubricant.
- A low conductor of electrical current.
- Refractory, resistant to high temperature.
- **The EU classified it as a strategic mineral in 2017.**
- One of the sources of graphene and of carbon fibre composites.
 - **Main producing countries: China 77%, Madagascar 6%, Mozambique 6% (2023)**
 - **Main refining country: China 89% (2023) (Benchmark Minerals) (USGS)**

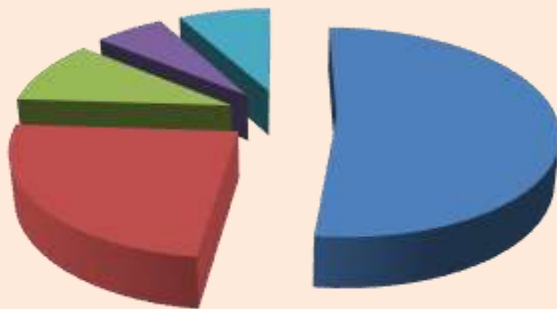


Graphite is not recycled a commercial level, but processes are being studied for its recycling (USGS) (ECGA)



GRAPHITE (carbon)
Huelma (Jaén)

USES (natural graphite)



- batteries 52%
- refractories 24%
- metal foundries 10%
- lubricants/friction 6%
- others 8%

Source: Wood Mackenzie 2023

REFERENCES AND LINKS

- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
- QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCH GmbH & Co, 2007
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- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <https://ecga.net/main-uses-of-graphite/>
- <https://www.usgs.gov/centers/national-minerals-information-center/graphite-statistics-and-information>



GYP SUM

- Hidrated calcium sulfate.
- A very soft mineral that is soluble in water.
- Not a good heat conductor (therefore a good insulator)
- Obtained from evaporite deposits, but recently, substantial amounts of gypsum have also been obtained from flue gas desulfuration (FGD).
- Main producing countries: EUA 14%, Iran 10%, Spain 7%, China 14% (2023) (USGS)



Gypsum is recycled from prefabricated gypsum products.

Recycled gypsum is used mainly as a corrector of agricultural soils. It is reused in plasterwork, and in treatment of drinking water.



GYSUM (calcium sulfate)
 Vinaixa (Les Garrigues) Catalonia

USES



Source: Data Intelo 2020



REFERENCES AND LINKS


- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
- QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCH GmbH & Co, 2007
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- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <http://www.knauf.es> <https://www.eurogypsum.org/>
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INDIUM (In) [Z=49]

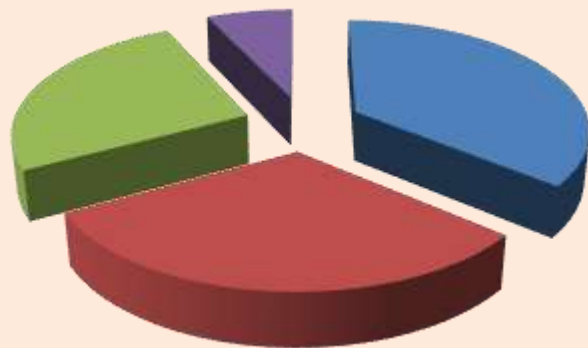
- A relatively rare metal.
- Light, soft, ductile and malleable.
- A good electrical conductor.
- Melts at a low temperature (157°C).
- **The EU classified it as a strategic metal in 2017.**
- Found in sphalerite (as a byproduct)
- **Main refining countries: China 66%, Republic of Korea 20% (2023)(USGS)**



SPHALERITE (zinc sulfide with indium)
Picos de Europa (Santander)

 Indium is recovered from electronic equipment that contains indium-tin oxide (ITO) flat panel displays.

USES



- flat screens (ITO) 36%
- semiconductor 31%
- solders & alloys 26%
- others 7%

Source: Gran View Research 2023




REFERENCES AND LINKS

GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
 QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCH GmbH & Co, 2007
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<https://www.indium.com>
<https://www.usgs.gov/centers/national-minerals-information-center/indium-statistics-and-information>



IRON (Fe) [Z=26]

- Essential for all living beings.
- The fourth most common element on the Earth's crust.
- Pure iron is soft and fragile.
- When carbon is added, it becomes harder and stronger.
- Obtained from hematite and magnetite.
- **Main mineral producing countries: Australia 38%, Brazil 18%, China 11% (2023)(USGS)**
- **Main raw steel producing countries: China 53%, (2023)(USGS)**

 The main source of recycling of iron is scrap metal and steel, mainly from scrapping cars. A total of 62% of energy is saved compared to production with mineral iron.



HEMATITE (iron oxide)
Lucena (Alcalatén)

USES



Source: Statista 2023



REFERENCES AND LINKS

- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
- QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCH GmbH & Co, 2007
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- <https://www.eurofer.eu/>
- <https://www.usgs.gov/centers/national-minerals-information-center/iron-ore-statistics-and-information>
- <https://www.usgs.gov/centers/national-minerals-information-center/iron-and-steel-statistics-and-information>

KAOLINITE

- Hydrated aluminium silicate.
- A basic component of many clays.
- White and soft to the touch.
- Gains plasticity in contact with water.
- Low thermal and electrical conductivity.



An insignificant amount is recycled directly, but kaolinite consumption can be reduced by recycling paper.



KAOLINITE (hydrated aluminium silicate)
Ares d'Alpont (Els Serrans) Catalonia

USES



- paper 43%
- ceramics 16%
- paint&coatings 11%
- fiberglass 11%
- cosmetics 9%
- pharmaceuticals&medical 5%
- plastic and rubber 5%

Source: Market Research 2023



REFERENCES AND LINKS

SANZ et al., *Elements and Mineral Resources*. Springer Textbooks. Switzerland, 2022
<https://www.imerys.com/minerals/kaolin> <http://www.ima-europe.eu>



LEAD (Pb) [Z=82]

- A soft, ductile, malleable, extremely heavy metal.
- Highly resistant to corrosion.
- Absorbs sound and radioactivity well.
- Due to its toxicity, its used only in certain applications.
- Obtained from galena.
 - Main mineral producing countries: China 44%, Australia 10%, Mexico 6%, EUA 6%, Peru 5% (2023)(USGS)
 - Main refining countries: China and Australia (2023)(Statista)

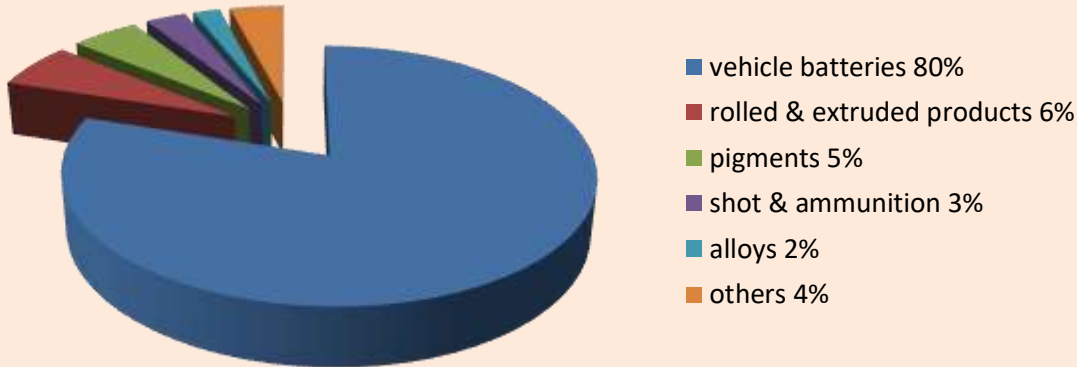


Its recycling is 60%, mainly from batteries (it is the most recycled metal of all). It can be reused indefinitely without loss of features



GALENA (lead sulfide)
El Molar (Priorat) Catalonia

USES



Source: International Lead & Zinc 2023

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LITHIUM (Li) [Z=3]

- An alkali metal.
- This is the lightest metal that is known.
- It has a very high electrochemical potential.
- Its presence in the human body is essential for a person's mental equilibrium.
- Obtained from spodumene, lepidolite, petalite and lithium-rich brines.
- **The EU classified lithium as a strategic metal in 2020.**
- **Main producing countries: Australia 47%, Chile 24%, China 17% (2023) (USGS)**
- **Main refining countries: China 58%, Chile 29%, Argentina 10% (2023) (Statista)**

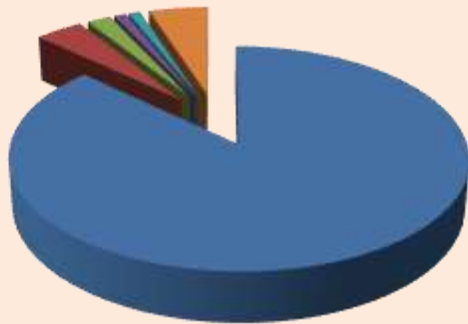


SPODUMENE (aluminium & lithium silicate)
Namibe (Angola)



Lithium battery recycling is growing. The reuse of lithium batteries used in vehicles to store domestic energy, is increasing

USES



- recharg. batteries 87%
- ceramic and glass 4%
- lubricants 2%
- casting mold powders 1%
- medical 1%
- others 5%

Source: Statista 2023



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<https://europeanlithium.com/>
<https://www.usgs.gov/centers/national-minerals-information-center/lithium-statistics-and-information>

MAGNESIUM (Mg) [Z=12] and *magnesite*

- An alkaline earth metal.
- Lighter than aluminium, and highly resistant to corrosion.
- An essential element for the human body and for the chlorophyll of plants, which is vital in photosynthesis.
- Obtained mainly from magnesite, magnesium chloride from brine and seawater.
- **The EU classified magnesium as a strategic metal in 2017.**
- **Main refining country: China 89% (2023)(USGS)**



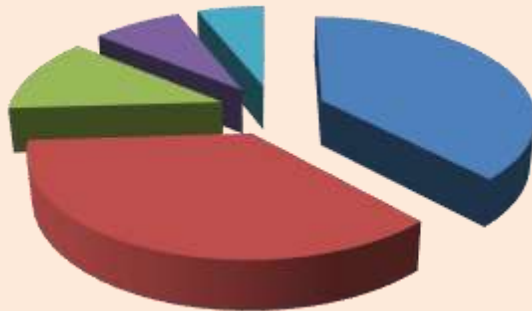
In the EU, 33% of magnesium is recycled. Recycling of magnesium has increased in recent years.

- Magnesite is magnesium carbonate that is used to manufacture refractory materials, in agriculture, livestock and construction.



MAGNESITE (magnesium carbonate)
Eugui (Navarra)

USES



- aluminium alloying 38%
- die casting 36%
- iron & steel 12%
- metal reduction 8%
- other 6%

Source: European Aluminium 2021

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MANGANESE (Mn) [Z=25]

- A very hard, brittle metal.
- Refractory and easily oxidised.
- Obtained from pyrolusite and other manganese oxides.
- The EU classified it as a strategic material in 2023.
- Main producing countries: South Africa 36%, Gabon 23%, Australia 15% (2023)(USGS)
- Main refining country: China 94% (2023) (Manganese X)



PYROLUSITE (manganese oxide)
Tosa d'Alp (Berguedà) Catalonia



The main source of recovery of manganese is scrap metal produced during steel manufacture.

USES



Source: Eramet

- iron/steels 90%
- aluminium alloys 6%
- batteries 3%
- others 1%



REFERENCES AND LINKS

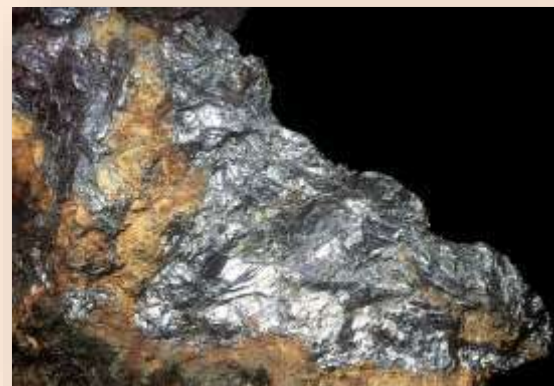
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- <http://eurometaux.eu> <http://eramet.com> <https://www.manganesenergycorp.com/>
<https://www.usgs.gov/centers/national-minerals-information-center/manganese-statistics-and-information>

MOLYBDENUM (Mo) [Z=42]

- A metal that is a very good thermal and electrical conductor.
- Has a low expansion coefficient.
- Refractory (melts at 2625°C).
- Obtained from molybdenite.
- **Main producing countries: China 42%, Chile 18%, Perú 14% (2023) (USGS)**



Molybdenum is recycled from catalysts and steel scrap. A total of 30% of the molybdenum that is consumed in the USA is recycled from scrap metal.



MOLYBDENITE (molybdenum sulfide)
Gualba (Vallès Oriental) Catalonia

USES



- stainless steel 25%
- other steels 38%
- lubricants/catalysts 13%
- superalloys 8%
- others 16%

Source: IMO A 2022

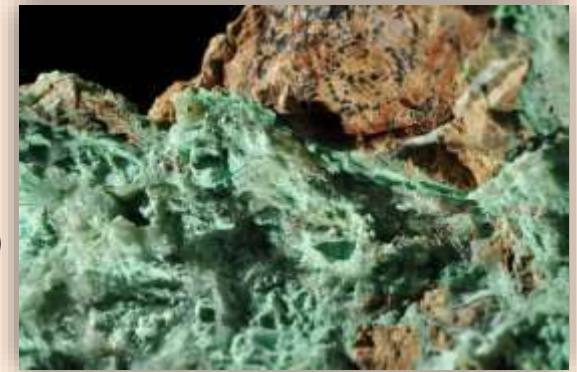
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- <https://www.usgs.gov/centers/national-minerals-information-center/molybdenum-statistics-and-information>



NICKEL (Ni) [Z=28]

- A ductile, malleable metal.
- Slightly ferromagnetic at room temperature.
- Melts at 1455 °C.
- Resistant to corrosion, does not oxidise.
- Extracted from laterites (népouite, garnierite) and sulphides (pentlandite, skutterudite)
- **The EU classified it as a strategic material in 2023.**
- **Main producing countries: Indonesia 50%, Philippines 11%, New Caledonia 6% (2023)(USGS)**
- **Main refining countries: China 35%, Indonesia 15%, Japan 8% (2023)(Statista)**



NÉPOUITE (nickel silicate)
Népoui (New Caledonia)



Nickel is recycled from scrap metal of stainless steel and others steels that contain this metal. Stainless steel on the market contains an average of 65% of recycled nickel.

USES



Source: Statista 2023

REFERENCES AND LINKS

GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
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Batterie Ni-MH (Prius car)



NIOBIUM (Nb) [Z=41]

- A metal that is resistant to corrosion.
- Ductile and hard.
- A relatively rare metal.
- **The EU classified it as a strategic metal in 2017.**
- Found in columbite-tantalite (*coltan*), pyrochlore and euxenite.
- **Main producing countries: Brazil 90%, Canada 8% (2023)(USGS)**
- **Main producing ferroniobium and Nb-metal countries: Brazil and Canada (2023)(USGS)**



Niobium is recycled from scrap metal and steels containing it.



COLUMBITE-TANTALITE (*coltan*) (niobium&tantalum oxides)
Musaca (Rwanda)

USES



- ferroniobium (steels) 57%
- superalloys 43%
- electronics/magnets 10%

Source: USGS 2023



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PHOSPHORUS (P) [Z=15] and *phosphorite*

- A very reactive non-metal; it oxidises spontaneously in contact with oxygen and emits light (*phosphorescence*).
- Insoluble in water.
- An essential nutrient for plants and animals.
- Adenosine triphosphate (ATP) is the cells' energy store.
- Phosphorus is obtained from *phosphorite* (cryptocrystalline variety of apatite).
- The EU classified *phosphorite* as a strategic rock in 2017.
- Main mineral producing countries: China 41%, Morocco 16%, EUA 9% (2023)(USGS)



PHOSPHORITE (calcium phosphate)
Logrosán (Cáceres)



Phosphorus and *phosphorite* are not known to be recycled.

USES



Source: MGVM 2017



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- SANZ et al., *Elements and Mineral Resources*. Springer Textbooks. Switzerland, 2022
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PLATINUM (group)

- The platinum group is comprised of iridium, osmium, platinum, palladium, rhodium and ruthenium.
- These are noble, dense, malleable metals.
- Resistant to corrosion and high temperatures.
- **The EU classified them as strategic metals in 2017.**
- Very good catalysts in reactions.
- Associated with each other in nickel and copper sulfides and related minerals such as sperrylite.
- **Main producing countries: South Africa 55%, Russia 25%, Canada 9%, Zimbabwe 8% (2023) (Johnson Matthey)**



PLATINUM (native)
Chocó (Colombia)

 Most of the metals in the platinum group that are recycled are catalysts for vehicles, jewellery

USES



- automotive 65%
- chemical 11%
- industry 8%
- jewellery 8%
- investment 2%
- dental & biomedical 2%
- others 4%

Source: Johnson Matthey 2023

REFERENCES AND LINKS

- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
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- <https://www.usgs.gov/centers/national-minerals-information-center/platinum-group-metals-statistics-and-information>
- <https://ipa-news.com/index/about-pgms/the-six-metals.html>
- <https://matthey.com/>



POTASSIUM (K) [Z=19]

- An alkali metal.
- Reacts with water to produce hydrogen.
- Oxidises rapidly in air and vigorously in water, forming flames.
- An essential element in human, animal and plant life.
- Obtained from sylvite, water from certain seas (the Dead Sea) and salt flats.
- **Main producing countries: Canada 31%, Russia 19%, Belarus 15%, China 13%, Germany 6%, Israel 5%, Spain 1% (2024)(USGS)**



Cannot be recycled



SILVITE (potassium chloride)
Sallent (Bages) Catalonia

USES



- fertilizers 93%
- soaps/detergents 4%
- glass/ceramics 2%
- others 1%

Source: ICLiberia



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- <http://www.icliberia.com>
- <https://www.usgs.gov/centers/national-minerals-information-center/potash-statistics-and-information>

QUARTZ and silica sand

- This is a silicate (silicon oxide).
- It is hard (7 on the Mohs scale) and brittle.
- A very good abrasive.
- When a specific electrical current is applied between the ends of a quartz crystal, it vibrates at an exact frequency (resonant behaviour).
- It occurs in different forms with different uses:
 - * Macrocrystalline quartz: decoration, ferrosilicon, electronics.
 - * Cryptocrystalline quartz: manufacture of artificial stone (Silestone).
 - * Silica sand: manufacture of glass, abrasives, foundry moulds, carborundum.
- Recycled indirectly from glass recycling. The glass industry in Europe recycles 62% of silica sand.

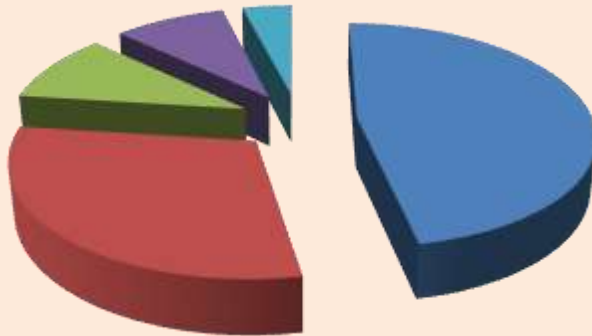


Hyaline QUARTZ (silicon oxide)
Chamonix (France)



Silica sand

USES of silica sand



- foundry 47%
- glass 30%
- chemical production 10%
- construction 9%
- others 4%

Source: MMR 2023



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GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
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RARE EARTHS

The following elements are known as the rare earths: lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), lutetium (Lu), yttrium (Y) and scandium (Sc).

They have physical and chemical properties that make them very useful in the manufacture of small, permanent and very strong magnets, high performance batteries, catalysts, LEDs, LCD screens, fluorescent lamps and lasers.

The EU classified RARE EARTHS as a strategic metals in 2017.

- Main producing countries: China 69%, EUA 11%, Burma 8% (2024)(USGS)

- Main refining countries: China 87%, Malaysia 12% (2022)(LE FIGARO)



Neodymium and dysprosium from wind turbines magnets, electric motors and hard disks are already being recycled, as lanthanum and nickel from Ni-MH batteries.

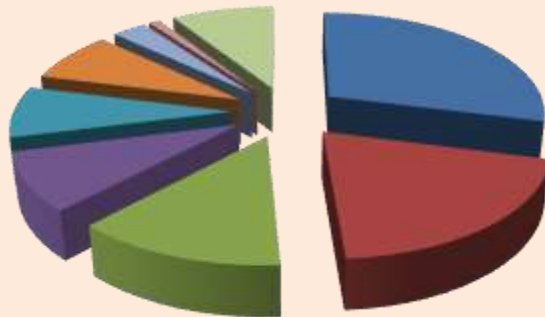


Clay impregnated with Rare Earths (China)



Monazite Minas Geraes (Brasil)

USES



Source: IRENA 2022

- permanent magnets 29%
- catalysts 20%
- polishes 13%
- metallurgy 9%
- glass 8%
- batteries 8%
- ceramics 3%
- phosphors 1%
- others 9%



REFERENCES AND LINKS

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SEPIOLITE

- Hydrated magnesium silicate.
- It is a special clay.
- Soft, light and porous.
- A good thermal insulator with a high capacity for absorption and adsorption.



Sepiolite is not known to be recycled.



SEPIOLITE
Vallecas (Madrid)

USES



- animal litter 60%
- animal feeds 25%
- industrial uses 14%
- others 1%

Source: Sepiolsa



REFERENCES AND LINKS

SANZ et al., *Elements and Mineral Resources*. Springer Textbooks. Switzerland, 2022

<http://www.sepiolsa.com>

<http://www.tolsa.com>

<http://www.ima-europe.eu>

SILVER (Ag) [Z=47]

- A noble metal that is soft, ductile and malleable.
- It has the highest electrical and thermal conductivity of all metals.
- It is the whitest and most reflective metal.
- Many silver salts are light-sensitive.
- Obtained from argentite, from argentiferous galena, and as a by-product of copper extraction (anode sludges).

Main producing countries: Mexico 25%, China 13%, Peru 12%, Chile 5% (2023) (USGS)

As much silver as possible is recycled. In the jewellery sector, 90% is recycled; in industry, between 40% and 50% is recycled.



SILVER (wires)
Poblet(Conca de Barberà) Catalonia

USES



Source: Silver Institute 2024

REFERENCES AND LINKS

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- <https://www.silverinstitute.org/>
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SODIUM (Na) [Z=11] and *halite (salt)*

- An alkali metal.
- Reacts strongly with water and releases H₂.
- Oxidises rapidly in air.
- A basic element in human and animal diets.
- Obtained from halite.
- Main producing countries: China 20%, EUA 14%, India 10%, Germany 6%, Canada 4%, Chile 4%, Spain 1% (2024)(USGS)
- The recycling of sodium and salt is insignificant.
- *Halite (common salt) is directly useful in food, water treatment and to prevent ice from forming on paths and roads.*



HALITE (sodium chloride)
Súria (Bages) Catalonia

USES of *halite*



- chemical processing 38%
- de-icing 22%
- water treatment 15%
- oil & gas 9%
- agriculture 6%
- others 10%

Source: Globe Mewswire 2022

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<https://eusal.com/>
<https://www.usgs.gov/centers/national-minerals-information-center/salt-statistics-and-information>



TALC

- A hydrated magnesium silicate.
- An excellent mineral for filler (plastics, ceramics, paints, paper...)
- White and greenish.
- Soft, smooth, light and hydrophobic.
- Resistant to temperatures of up to 1300°C.
- Low thermal and electrical conductivity.
- Found mainly in metamorphic rocks.
- **Main producing countries: China 20%, India 20%, EUA 8%, Brazil 7%, France 6% (2024) (USGS)**

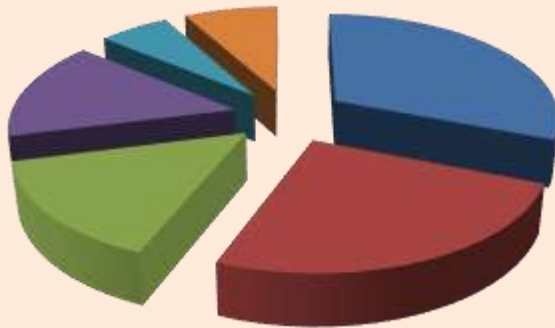


TALC (hidratat magnesiü silicate)
Maçanet de Cabrenys (Alt Empordà) Catalonia



Talc is not known to be recycled, but recycling paper and plastics, we will reduce their consumption.

USES



- ceramics 31%
- plastics and rubber 25%
- paints and coatings 15%
- pulp and paper 15%
- personal care 6%
- others 8%

Source: Mordor Intelligence 2021



REFERENCES AND LINKS

SANZ et al., *Elements and Mineral Resources*. Springer Textbooks. Switzerland, 2022

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<https://www.usgs.gov/centers/national-minerals-information-center/talc-and-pyrophyllite-statistics-and-information>

TANTALUM (Ta) [73]

- A relatively rare metal.
- Heavy, hard and resistant to corrosion.
- Has a high capacity to store electricity.
- Resistant to high temperatures (melts at 2996°C).
- **The EU classified tantalum as a strategic metal in 2017**
- Found in columbite-tantalite (*coltan*) and tantalite.
- **Main producing countries: DR. Congo 42%, Nigeria 19%, Brazil 10%, China 4%, Australia 2% (2024)(USGS)**
- **Main refining countries: Japan, Australia, EUA, China (2022) (Screen)**
- **The main source of recycling of tantalum is the reuse of scrap metal created in the process of manufacturing capacitors, electronic components, tools and superalloys based on this metal.**



COLUMBITA-TANTALITE (*coltan*) (niobium&tantalum oxides)
Musaca (Rwanda)

USES



- capacitors 36%
- superalloys 24%
- mill products 12%
- sputtering targets 11%
- carbides 9%
- others 8%

Source: JRC 2021

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- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
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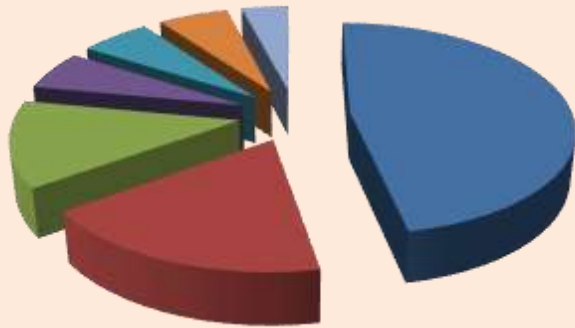
TIN (Sn) [Z=50]

- Malleable, ductile, a heavy metal.
- Does not react with oxygen or water; reacts with acids and bases.
- Melts at a low temperature (232 °C).
- Not a common metal.
- Can be found in cassiterite.
- **Main producing countries: China 23%, Burma 19%, Indonesia 18% (2023)(USGS)**
- **Main refining countries: China, Malaysia, Peru (2020)(SCREEN)**
- **In Europe, tin is recovered from printed circuit boards and tin cans.**



CASSITERITE (tin oxide)
Alt Empordà (Catalonia)

USES



Source: Tincorp 2023

- soldering 47%
- chemicals 18%
- tinplating 13%
- bronze/brass 6%
- glass 6%
- batteries 6%
- solar panels & others 4%



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- <https://www.usgs.gov/centers/national-minerals-information-center/tin-statistics-and-information>



TITANIUM (Ti) [Z=22]

- A very hard metal that and highly resistant to corrosion.
- Lighter than steel and rust-proof.
- Has a high melting point (1668 °C).
- Titanium oxide, a white pigment, is used mainly in paints, cosmetics, plastics, paper, ceramics and food.
- **The EU classified it as a strategic metal in 2020**
- Obtained from ilmenite and rutile.
- **Main producing countries: China 35%, Mozambique 20%, South Africa 14%, Australia 6% (2024)(USGS)**
- Titanium is recycled from off-cuts in processes such as stamping, and from metal that has already been used.



ILMENITE (titanium and iron oxide)
Sierra de l'Albarrana (Córdoba)



USES



Source: MGVM 2023

- aerospace 39%
- automotive & ships 24%
- paints & plastics 20%
- medical 8%
- military 7%
- others 2%



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<https://titanium.org>
<https://www.usgs.gov/centers/national-minerals-information-center/titanium-statistics-and-information>

TUNGSTEN (W) [Z=74]

- Also known as *wolfram*.
- A metal with a very high melting point (3410 °C).
- Denser than mercury.
- A semiconductor.
- **The EU classified it as a strategic metal in 2017.**
- Obtained from wolframite, ferberite and scheelite.
- **Main producing countries: China 83%, Vietnam 4%, Russia 3%, Bolivia 2% (2024)(USGS)**
- **Main refining country: China (2024)(USGS)**
- Large quantities are recycled from scrap metal and tungsten carbide (widia).



FERBERITE (iron and manganese wolframate)
Panasqueira (Portugal)

USES



Source: ITIA 2023

- tungsten carbides (widia) 65%
- steels and super-alloys 14%
- tungsten metal products 12%
- chemicals & others 9%



REFERENCES AND LINKS

- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
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VANADIUM (V) [Z=23]

- Ductile metal, resistant to oxidation.
- Very resistant to acids and bases.
- **The EU classified it as a strategic metal in 2017.**
- Obtained from magnetites rich in vanadium and carnotite.
- **Main producing countries: China 70%, Russia 21%, South Africa 8%, Brazil 5% (2024) (USGS)**
- **Main refining country: China (2024)(USGS)**



The quantity of vanadium recycled from spent chemical process catalysts is significant, and may compose as much as 40% of total vanadium catalysts. Small percentage of vanadium steel scrap is recycled.



VANADINITE (chloro-vanadate of lead)
Mibladen (Morocco)

USES



- HSLA steels + others 89%
- non-ferrous alloys 4%
- chemical catalysts 3%
- redox batteries 4%

Source: TTP Squared Inc 2022

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ZEOLITES

- A group of hydrated aluminosilicates with magnesium, potassium, calcium and sodium.
- They are soft, light and porous.
- Good thermal insulators and highly absorbent and adsorbent.
- High ion-exchange capacity.
- High affinity for ammonia (NH₃).
- The main (natural) zeolites are clinoptilolite and chabazite, and the synthetics.
- **Main natural zeolites producing countries: Slovakia 22%, China 15%, Rep. Korea 13%, Indonesia 12%, EUA 8% (2024) (USGS)**

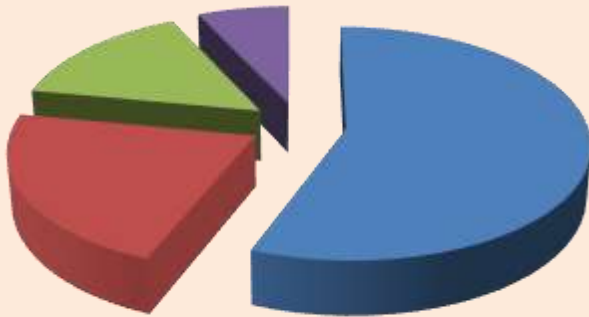


Zeolites are not known to be recycled, although they are used as drying agents, gas absorbers, water treatment agents and can be reprocessed and reused.



CHABAZITE
Iceland

USES



Source: Expert Market Research 2021

- detergents 56%
- catalysts 22%
- adsorbents 15%
- others 7%



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<http://www.zeolitanatural.com/english/agricandhort.htm>

<http://www.zeotechcorp.com>

<https://www.usgs.gov/centers/national-minerals-information-center/zeolites-statistics-and-information>

ZINC (Zn) [Z=30]

- A brittle metal.
- It has a low melting point (420°C).
- A fine layer of oxide protects the metal from further oxidation.
- Obtained mainly from sphalerite.
- **Main producing countries: China 33%, Peru 11%, Australia 8%, India 7%, Mexico 6%, EUA 6%, Bolivia 4% (2024) (USGS)**



Zinc is recycled from scrap metal, galvanisation waste, waste from the manufacture of pigments and other chemical products.



SPHALERITE (zinc sulfide)
Picos de Europa(Santander)

USES



- galvanizing 60%
- die-casting alloys 13%
- brass 11%
- oxide & chemicals 9%
- rolled zinc 5%
- others 2%

Source: ILZSG. 2023



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- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
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- <http://www.zinc.org>
- <http://www.ilzsg.org>
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Contributors

- **Photography's:**

Most of the photographs are by Joaquim Sanz i Balagué, except:

- Aluminium file: RENFE (AVE train) and Grup Agbar (tower)
- Barite file : Raúl Osorio (drilling well)
- Boron file: Javier Castelo (spent fuel pool)
- Calcite file: Salvador Redó (road)
- Calcite file: Albert Prat Carné (soccer field)
- Cobalt and niobium : Carlos Domínguez (plane engine)
- Gypsum file: Pura Alfonso Abella (arm in plaster)
- Lithium file: Black&Decker (drill)
- Manganese file : Ferrocarrils de la Generalitat de Catalunya (train and rails)
- Niobium file: Fosters+Partners (bridge)
- Níquel file: Toyota (battery)
- Quartz file: Silestone – Consentino, SA (kitchen)
- Rare Earths file: Oliva Torras, SA (laser)
- Talc file : Stora Enso (paper spool)
- Tin file: Oleguer Serra (organ)
- Zinc file: Tube-mill (tubes)