

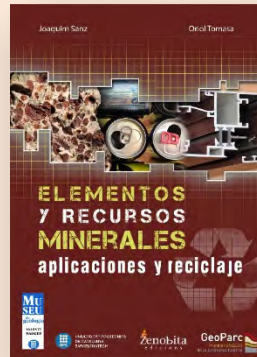


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# ELEMENTS and MINERAL RESOURCES: uses and recycling (cards to project in class)

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2020**

Catalan and spanish edition available at:



Catalan book on paper: Spanish book on paper:



Digital book (catalan & spanish)  
for PC, MAC, Android and IOS

[www.geomuseu.upc.edu](http://www.geomuseu.upc.edu)

## Contents [\(interactive\)](#)

Aluminium – *bauxite*

Antimony

*Barite*

Beryllium

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*Sepiolite*

Silver

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*Talc*

Tantalum

Tin

Titanium

Tungsten

Vanadium

*Zeolites*

Zinc

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

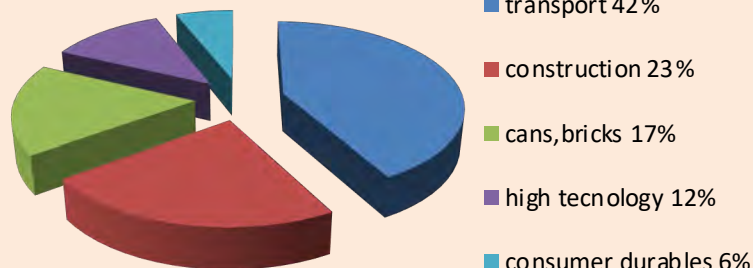
- The most abundant element in the Earth's crust.
- A good electrical conductor, malleable, ductile, soft and light.
- Provides a metal barrier that is impermeable to light, oxygen and bacteria.
- Obtained from bauxite.

♻️ The 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 (fused alumina)*  
*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>.*



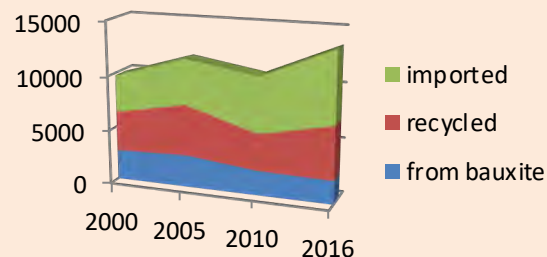
**BAUXITE** (rock formed from gibbsite, diaspore and boehmite)  
 mix of aluminium hydroxides and oxides  
*Miralles (Anoia) Catalonia*

## USES

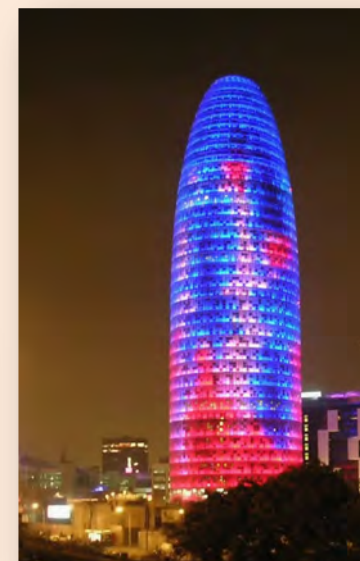


Source: European Aluminium 2017

## ORIGIN (thousands of tones)



Source: European Aluminium 2017



### REFERENCES AND LINKS

GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009  
<https://www.european-aluminium.eu/>

STWERTKA, Albert, *A guide of the elements, 3rd*. Oxford University Press, Inc. 2012  
<http://www.eurometaux.eu>

QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCH GmbH & Co, 2007  
<https://minerals.usgs.gov/minerals/pubs/commodity/aluminum/mcs-2019-alumi.pdf>

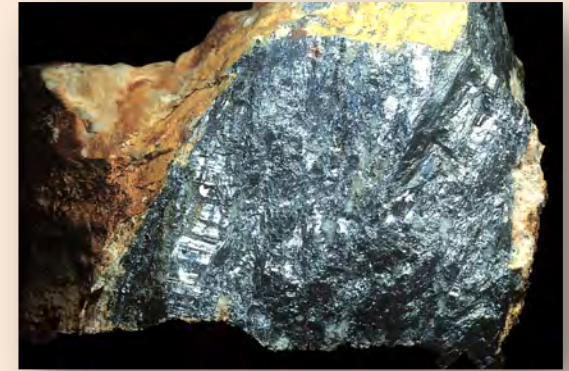
<https://roskill.com/market-report/metallurgical-bauxite-alumina/>

# 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.

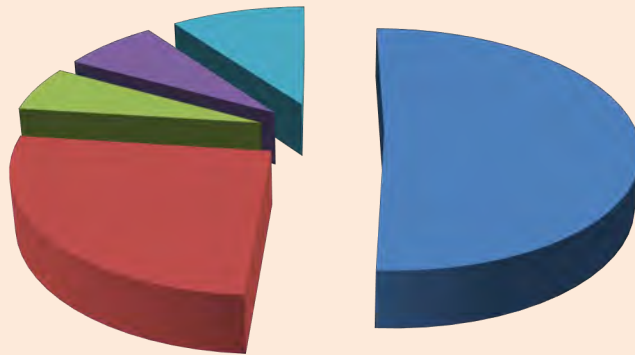


This metal is recycled from exhausted lead batteries (95%).



STIBNITE ( antimony sulfide)  
Abella (Ripollès) Catalonia

## USES



- flame retardants 51%
- lead batteries 26%
- ceramics/glass 6%
- PET plastics 7%
- others 10%

Source: Roskill 2018



### REFERENCES AND LINKS

- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCH GmbH & Co, 2007
- <http://www.eurometaux.eu>    <http://www.antimony.com/>
- <https://minerals.usgs.gov/minerals/pubs/commodity/antimony/mcs-2019-antim.pdf>
- <https://roskill.com/market-report/antimony/>

# 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.

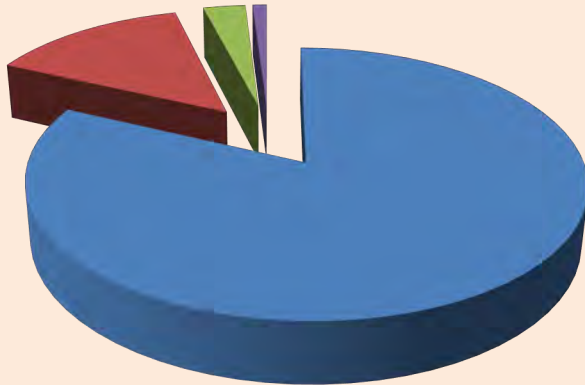


A considerable amount of barite is recovered from well-drilling mud.



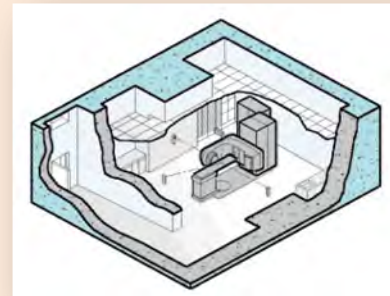
BARITE (barium sulphate)  
Espinelves (Osona) Catalonia

## USES



- drilling mud 82%
- plastics/paints 14%
- barite concrete 3%
- medicine 1%

Source: Market Publishers 2017



### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <https://minerals.usgs.gov/minerals/pubs/commodity/barite/mcs-2019-barit.pdf>
- <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 and high toxicity.
- Obtained from beryl and found in emerald and aquamarine.
- The EU classified beryllium as a strategic metal in 2017.

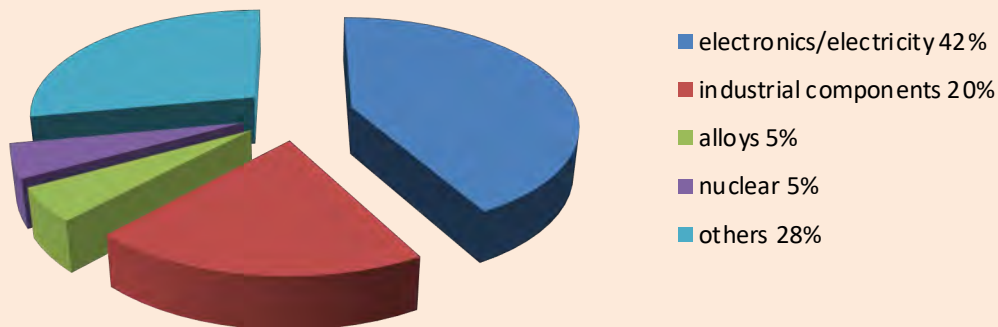


A total of 20% of the beryllium that is consumed is recycled from scrap metal obtained from the manufacture of products with this metal.



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

## USES



Source: USGS 2018




### 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  
 STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012  
<http://eurometaux.eu>      <http://beryllium.eu/>  
<https://minerals.usgs.gov/minerals/pubs/commodity/beryllium/mcs-2019-beryl.pdf>

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

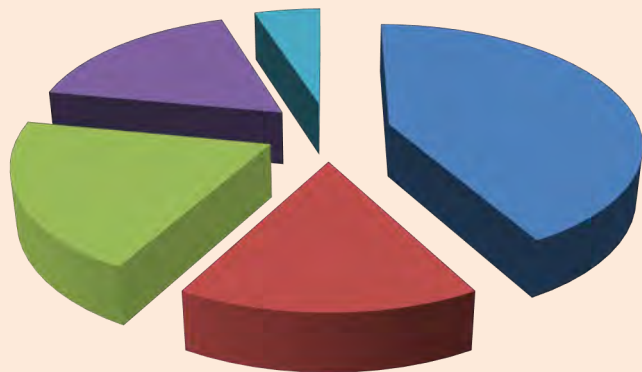
- A metalloid semiconductor.
- Very hard.
- Obtained from borax, ulexite, colemanite, and boron-rich brines.
- The EU classified borates as a strategic minerals in 2017

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



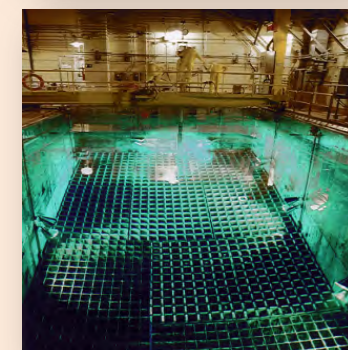
**BORON-RICH BRINES**  
Salar de Uyuni (Bolivia)

## USES



- fibreglass 42%
- borosilicate glass 16%
- ceramics 20%
- agriculture 17%
- others 5%

Source: Roskill 2018



### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <https://minerals.usgs.gov/minerals/pubs/commodity/boron/mcs-2019-boron.pdf>
- <https://roskill.com/market-report/boron/>

# CALCITE and limestone

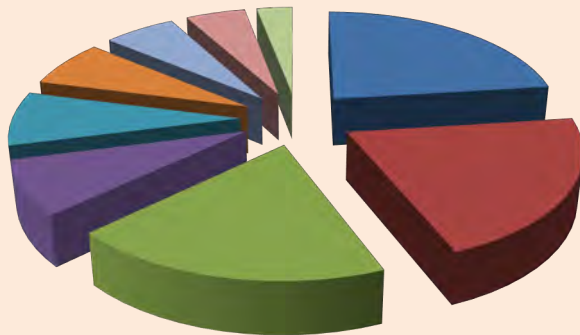
- A calcium carbonate; brittle and not very hard.
- Reacts with acids and effervesces.
- A mineral that forms rocks such as limestones and marbles.

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.



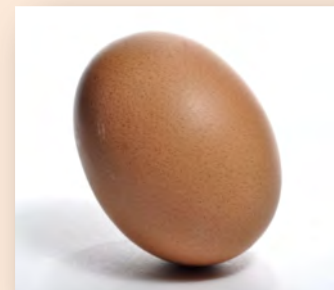
CALCITE (calcium carbonate)  
Illes Medes (Baix Empordà) Catalonia

## USES OF LIMESTONE



- iron & steel 23%
- paper 21%
- construction 19%
- water/gas treatment 8%
- agriculture/poultry raising 8%
- paints 7%
- chemical industry 6%
- plastics/rubbers 5%
- others 3%

Source: IMA Europe



### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <http://www.ima-europe.eu> [http://www.reverteminerals.com/index\\_en.php](http://www.reverteminerals.com/index_en.php)
- <https://roskill.com/market-report/ground-precipitated-calcium-carbonate/>

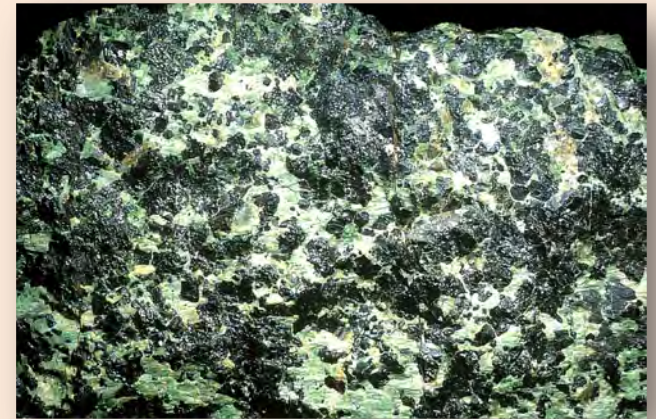


# CHROMIUM (Cr) [Z=24]

- 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.

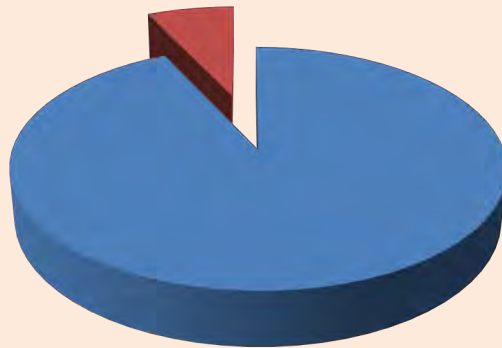


- In 2017, recycled chromium made up 30% of total chromium, and was obtained from the recycling of stainless steels that contain this metal.



CHROMITE (chromium oxide)  
Turkey

## USES



- steels and chromates 93%
- refractory bricks, pigments 7%

Source: Roskill 2018

### 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  
 STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012  
<https://www.eurometaux.eu/about-our-industry/introducing-metals/>  
<https://minerals.usgs.gov/minerals/pubs/commodity/chromium/mcs-2019-chrom.pdf>  
<https://roskill.com/market-report/chromium/>



# COBALT (Co) [Z=27]

- A metal with magnetic properties.
- High melting point (1493 °C).
- Heavy.
- The EU considered that it was a strategic metal in 2017.
- Mainly produced as a byproduct from nickel minerals (skutterudite), copper minerals (carrollite), as well, cobalt minerals like cobaltite.

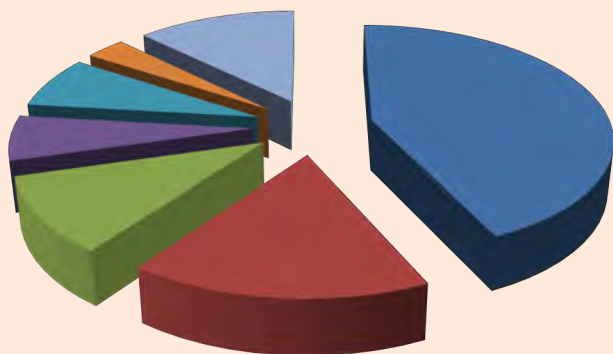


Cobalt is recycled from scrap metal generated during the manufacture of products that contain this metal, from cathodes Li-ion batteries and catalyst applications



CARROLLITE (copper, cobalt and nickel sulfide)  
Kambobwe (D.R. Congo)

## USES



- batteries 41%
- superalloys 16%
- hard metals 10%
- ceramics/pigments 6%
- catalysts 7%
- magnets 3%
- others 12%

Source: COBC 2017

### REFERENCES AND LINKS

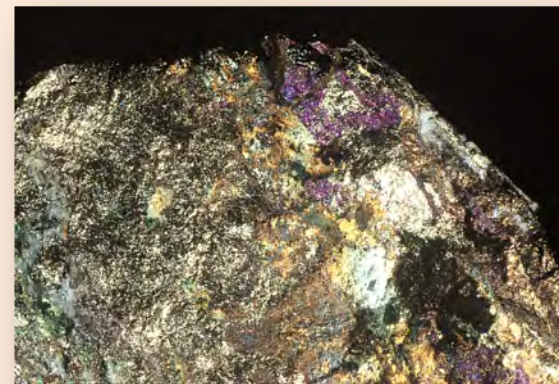
GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009  
 QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCH GmbH & Co, 2007  
 STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012  
<http://www.eurometaux.eu>    <https://www.cobaltinstitute.org/>  
<https://minerals.usgs.gov/minerals/pubs/commodity/cobalt/mcs-2019-cobal.pdf>  
<https://roskill.com/market-report/cobalt/>



# COOPER (Cu) [Z=29]

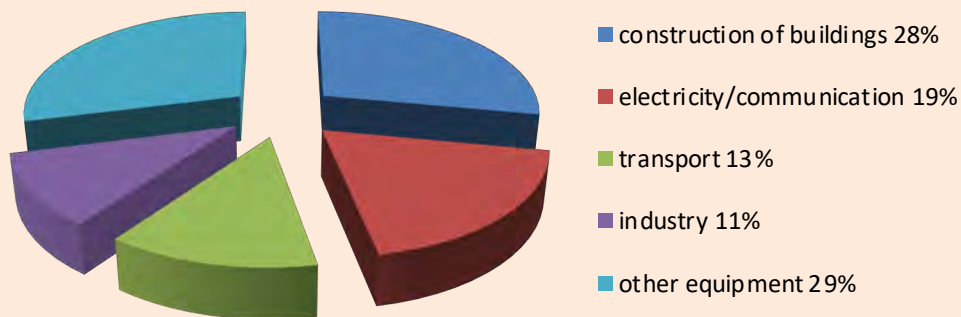
- A metal, a very good electrical and thermal conductor.
- Malleable, ductile and dense. Resistant to rusting.
- Has antimicrobial properties.
- Obtained from chalcopyrite, bornite, chalcocite and oxidised minerals such as brochantite and antlerite.

- 100% recyclable, with no loss of quality.
- Recycling copper reduces SO<sub>2</sub> emissions by 86%, CO<sub>2</sub> emissions by 94%, and the generation of solid waste by 99%. Sixty per cent less energy is consumed, and 98% less water.

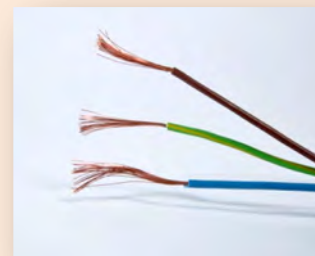


CHALCOPIRITE (cooper and iron sulfide)  
El Brull (Osona) Catalonia

## USES



Source: IWCC/ICA 2017



### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <https://copperalliance.eu>
- <https://eurometaux.eu/about-our-industry/introducing-metals/>
- <https://www.lafarga.es/en/the-group/the-copper-museum/introduction>
- <https://minerals.usgs.gov/minerals/pubs/commodity/copper/mcs-2019-coppe.pdf>
- <https://roskill.com/market-report/copper-demand-to-2035/>

# 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.



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



Source: Mordor Intelligence 2018



### REFERENCES AND LINKS

- <http://www.llansasa.com>
- <https://www.ima-europe.eu/about-industrial-minerals/industrial-minerals-ima-europe/feldspar>
- <https://minerals.usgs.gov/minerals/pubs/commodity/feldspar/mcs-2019-felds.pdf>

# 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.

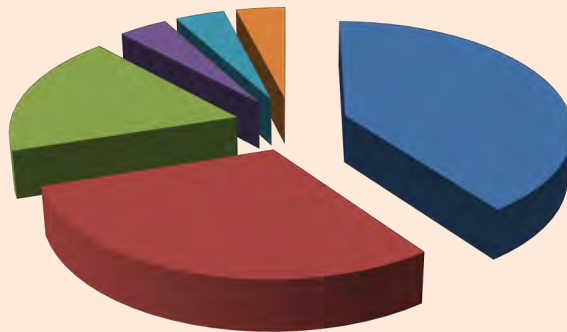


- Primary aluminum producers recycle HF and fluorides from smelting operations.
- Fluorite is only recycled in very small amounts
- The main uses of fluorite are in the extraction of hydrofluoric acid, in the iron and aluminium foundry, and in the manufacture of glass as a fluidising agent.



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

## USES (fluorite)



- hydrofluoric acid 40%
- steel foundry 30%
- aluminium foundry 18%
- cement 4%
- glass/ceramic 4%
- electrodes&others 4%

Source: USGS

### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <http://www.minersa.com/eng/>
- <https://minerals.usgs.gov/minerals/pubs/commodity/fluorspar/mcs-2019-fluor.pdf>
- <https://roskill.com/market-report/fluorspar/>



# GALLIUM (Ga) [Z=31]

- A ductile, malleable metal.
- Liquid at a temperature of 30°C.
- A rare metal and a semiconductor.
- The EU considered it to be a strategic metal in 2017.
- Found in bauxite and sphalerite.

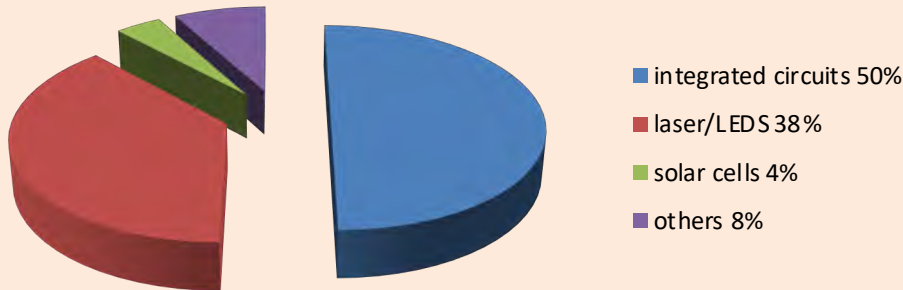


New scrap metal generated in the manufacture of electronic components made with gallium arsenide can be recycled.

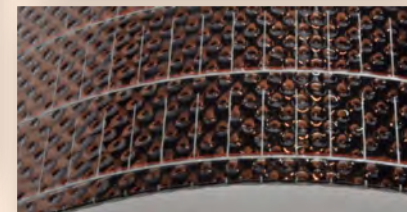


BAUXITE (aluminium hydroxides & oxides with gallium)  
*Fontespatria (Matarranya)*

## USES



Source: Roskill 2016



### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <http://eurometaux.eu>
- <https://minerals.usgs.gov/minerals/pubs/commodity/gallium/mcs-2019-galli.pdf>
- <https://roskill.com/market-report/gallium/>

# 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.

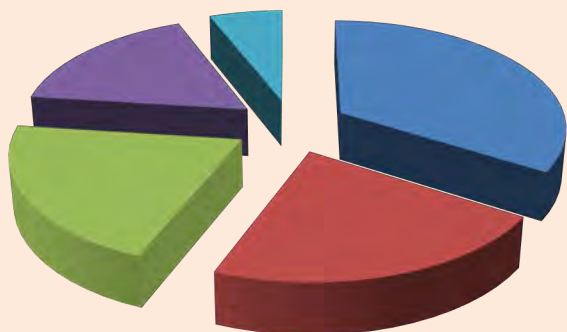


Approximately 30% of the germanium that is consumed worldwide is from recycled sources. In the process of manufacturing optical apparatus, over 60% of germanium is reused.



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

## USES

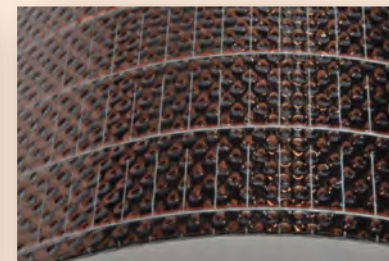


- fibre optics/lasers 34%
- infrared optics 22%
- catalysts 21%
- solar cells 17%
- others 6%

Source: mcgroup 2018

### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <https://eurometaux.eu/about-our-industry/introducing-metals/>
- <https://minerals.usgs.gov/minerals/pubs/commodity/germanium/mcs-2019-germa.pdf>



# 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.

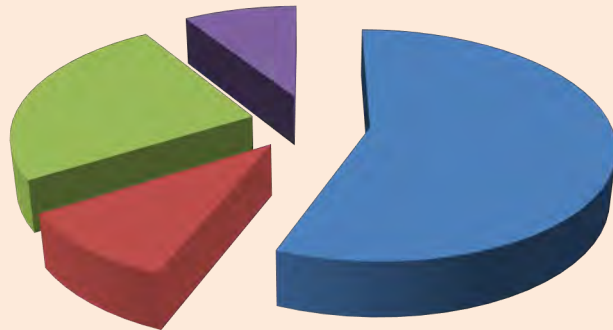


A total of 100% is reusable and the maximum amount possible is recovered from jewellery and old electronic equipment.

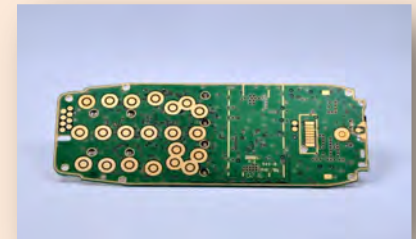


GOLD (native)  
Nevada (USA)

## USES



- jewellery 56%
- industry 10%
- investment 25%
- others 9%



Source: GFMS, Thomson Reuters 2017

### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <http://minerals.usgs.gov/minerals/pubs/commodity/gold/mcs-2019-gold.pdf>



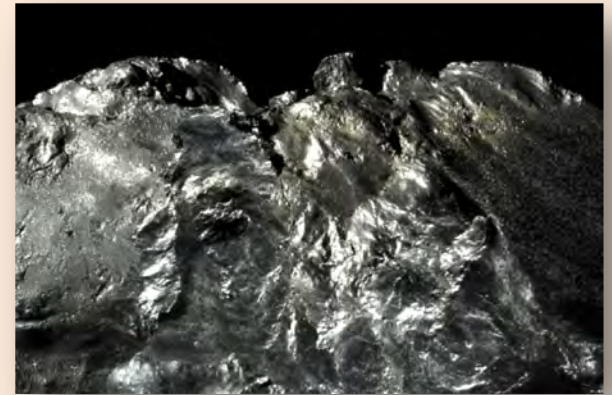


# GRAPHITE (C) [Z=6]

- 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.

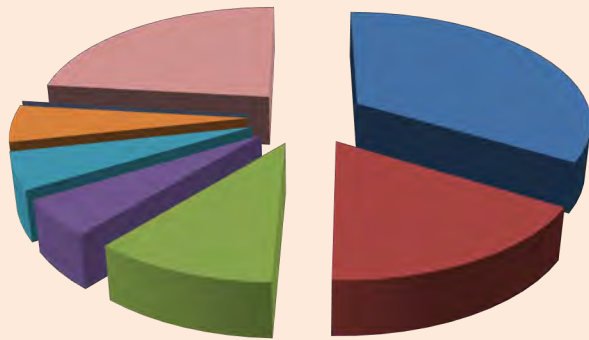


The market of refractory recycled graphite is growing.



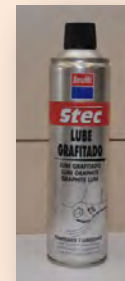
GRAPHITE (carbon)  
Huelma (Jaén)

## USES



Source: Roskill 2017

- electrodes 32%
- refractories 16%
- recarbursing 10%
- batteries 5%
- foundries 5%
- lubricant 5%
- friction products 5%
- others 22%



### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <https://www.graphenea.com/>
- <https://minerals.usgs.gov/minerals/pubs/commodity/graphite/mcs-2019-graph.pdf>
- <https://roskill.com/market-report/natural-synthetic-graphite/>

# GYPSUM

- 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).

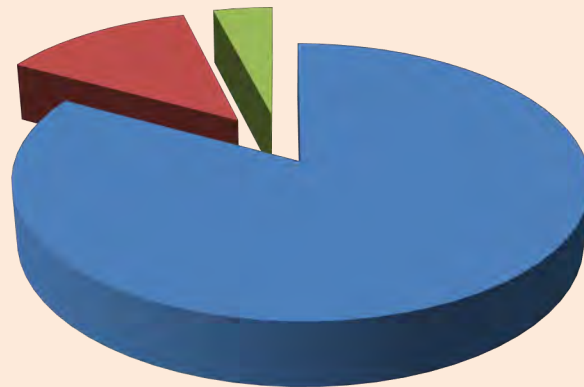


Gypsum is recycled from prefabricated gypsum products. Recycled gypsum is used mainly as a corrector of agricultural soils. It is reused in plasterwork, and in treatment of drinking water.



GYSUM (calcium sulfate)  
Vinaixa (Les Garrigues) Catalonia

## USES



- plasterboard/gypsum derivatives 83%
- cement 13%
- agriculture 4%



Source: USGS


### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <http://www.knauf.es>
- <https://minerals.usgs.gov/minerals/pubs/commodity/gypsum/mcs-2019-gypsu.pdf>
- <https://roskill.com/market-report/gypsum-and-anhydrite/>



# INDIUM (In) [Z=49]

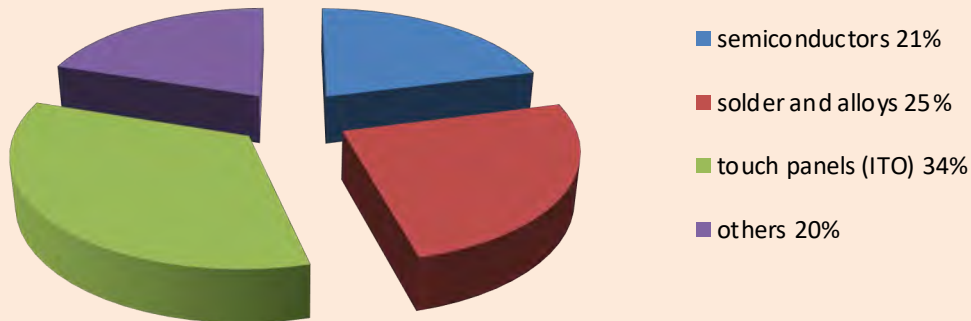
- A relatively rare metal.
- Light, soft, ductile and malleable.
- A good electrical conductor.
- Melts at a low temperature (157°C).
- The EU classified it as a strategic metal in 2017.
- Found in sphalerite.

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



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

## USES

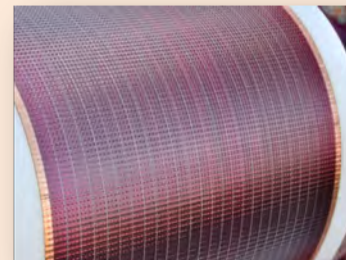


Source: Marketintellica 2018



### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <https://minerals.usgs.gov/minerals/pubs/commodity/indium/mcs-2019-indiu.pdf>
- [www.indium.com](http://www.indium.com)
- <https://roskill.com/market-report/indium/>



# 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.

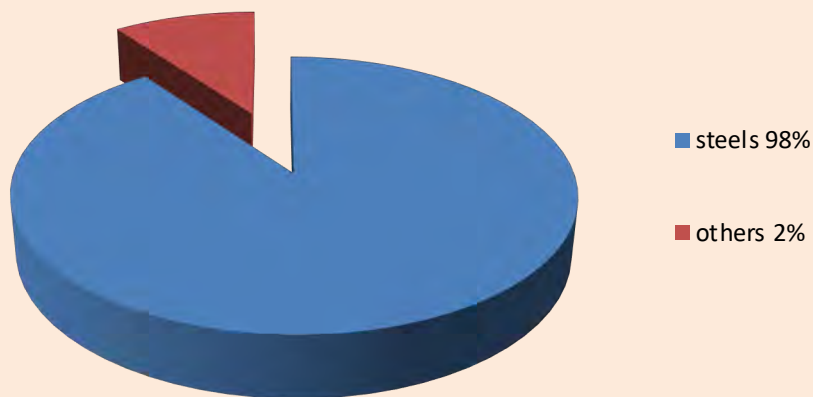


The main source of recycling of iron is scrap metal and steel, mainly from scrapping cars. A total of 68% of energy is saved compared to production with mineral iron.



HEMATITE (iron oxide)  
*Llucena (Alcalatén)*

## USES



Source: Eurofer 2017

### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <http://www.eurofer.org/>
- [https://minerals.usgs.gov/minerals/pubs/commodity/iron\\_&\\_steel\\_scrap/mcs-2019-fescr.pdf](https://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel_scrap/mcs-2019-fescr.pdf)



# 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.

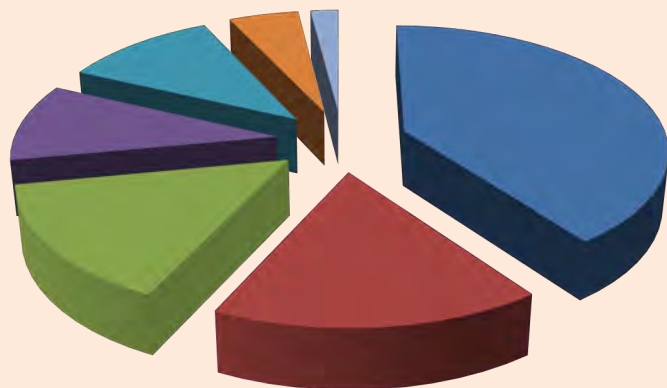


An insignificant amount is recycled directly, but kaolinite consumption can be reduced by recycling paper.



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

## USES



- paper 40%
- paints/buildings 17%
- ceramics 15%
- fibreglass 10%
- plastics/rubber 11%
- pharmaceuticals 5%
- others 2%

Source: Digital Journey 2018



### REFERENCES AND LINKS

- <https://imerys-kaolin.com/en/>
- <http://www.ima-europe.eu>
- <https://sciencestruck.com/kaolin-uses>
- <https://roskill.com/market-report/kaolin/>



# 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 use in certain applications is declining.
- Obtained from galena.

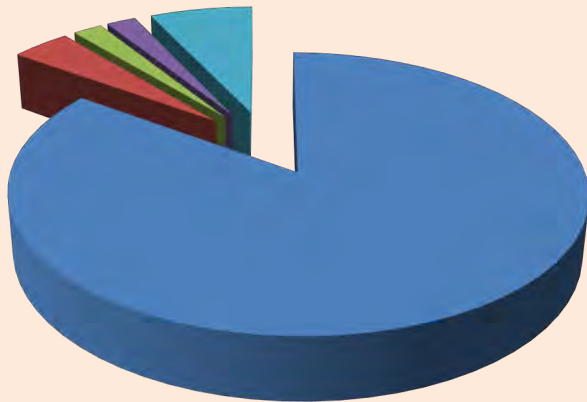


Around 82% is recycled, mainly from electric batteries.



GALENA (lead sulfide)  
El Molar (Priorat) Catalonia

## USES



- batteries 85%
- construction 4%
- shot/ammunition 2%
- alloys 2%
- others 7%

Source: [ila-lead.org](http://ila-lead.org)

### REFERENCES AND LINKS

- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
- QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCHR GmbH & Co, 2007
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <http://www.ila-lead.org>
- <https://minerals.usgs.gov/minerals/pubs/commodity/lead/mcs-2019-lead.pdf>




# LITHIUM (Li) [Z=3]

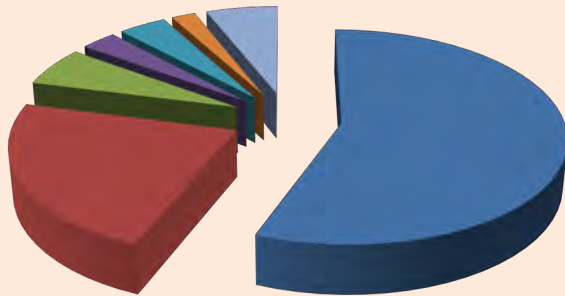
- An alkali metal.
- This is the lightest metal that is known.
- It has a very high electrochemical potential.
- Its presence in the human body is essential for a person's mental equilibrium.
- Obtained from spodumene, lepidolite, petalite and lithium-rich brines.



SPODUMENE (aluminium & lithium silicate)  
Namibe (Angola)

 An increasing number of lithium batteries are recycled, due to their rising use on the market.

## USES



Source: USGS 2018

- recharg. batteries 56%
- ceramics and glass 23%
- lubricant greases 6%
- casting mold powders 3%
- polymer production 4%
- air treatment 2%
- other uses 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  
 STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012  
<https://minerals.usgs.gov/minerals/pubs/commodity/lithium/mcs-2019-lithi.pdf>  
<https://roskill.com/market-report/lithium/>  
<https://roskill.com/market-report/lithium-ion-batteries/>

# 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.



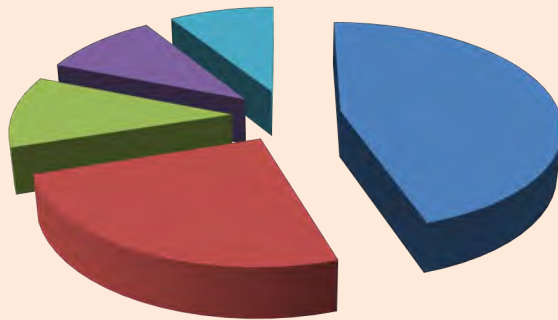
In the EU, 33% of magnesium is recycled. Recycling of magnesium has increased in recent years.

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



MAGNESITE (magnesium carbonate)  
*Eugui (Navarra)*

## MAGNESIUM USES

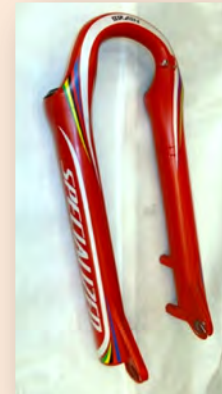


- castings titanium/aluminium 45%
- aluminium base alloys 25%
- desulfurization iron and steel 11%
- reduction agent metals production 10%
- others 9%

Source: USGS 2018

### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <http://www.roullier.com/en/> <http://www.intlmag.org>
- <https://minerals.usgs.gov/minerals/pubs/commodity/magnesium/mcs-2017-mgmet.pdf>
- <https://roskill.com/market-report/magnesium-metal/>





# MANGANESE (Mn) [Z=25]

- A very hard, brittle metal.
- Refractory and easily oxidised.
- Obtained from pyrolusite and other manganese oxides.

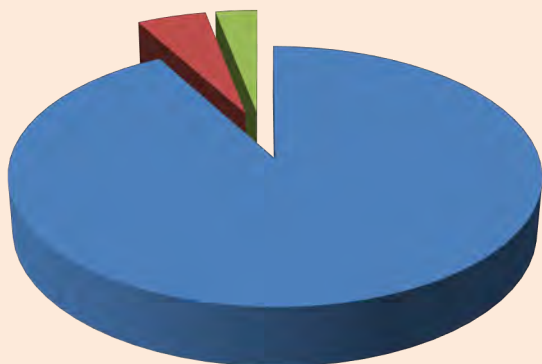


The main source of recovery of manganese is scrap metal produced during steel manufacture.



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

## USES

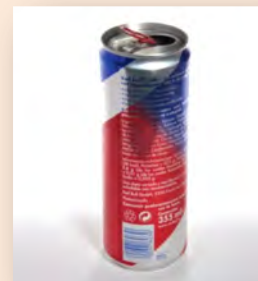


- iron/steels 92%
- aluminium alloys 5%
- batteries 3%

Source: Roskill

### REFERENCES AND LINKS

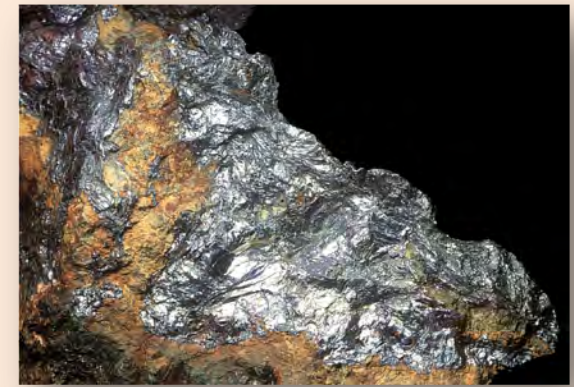
GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009  
 QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCH GmbH & Co, 2007  
 STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012  
<http://eurometaux.eu>  
<https://minerals.usgs.gov/minerals/pubs/commodity/manganese/mcs-2019-manga.pdf>  
<https://roskill.com/market-report/manganese/>



# MOLYBDENUM (Mo) [Z=42]

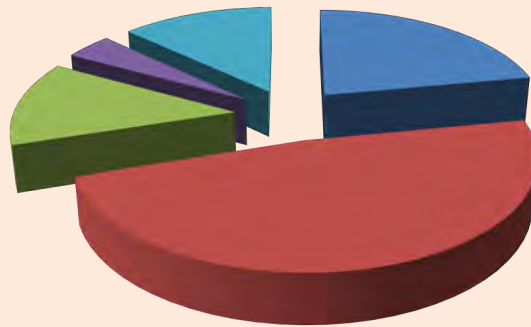
- A metal that is a very good thermal and electrical conductor.
- Has a low expansion coefficient.
- Refractory (melts at 2625°C).
- Obtained from molybdenite.

Molybdenum is recycled from stainless steel and other steels. 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 steels 22%
- other steels 48%
- lubricants/catalysts 13%
- super alloys 4%
- others 13%

Source: IMO A 2018

### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <https://minerals.usgs.gov/minerals/pubs/commodity/molybdenum/mcs-2019-molyb.pdf>
- <http://www.molyfromstock.com/molybdenum-applications.php>
- <http://www.imoa.info/> <http://eurometaux.eu>
- <https://roskill.com/market-report/molybdenum/>



# 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 (nepouite) and byproduct of nickel, cobalt and copper sulfides

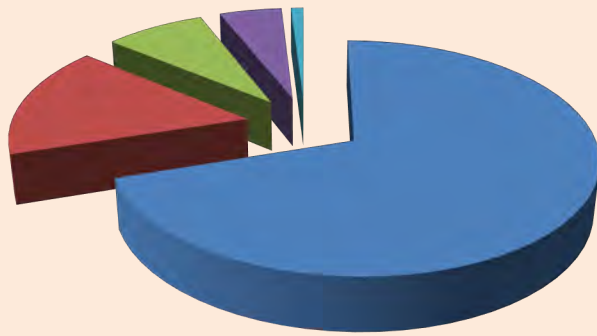


Nickel is recycled from scrap metal of stainless steel and others steels that contain this metal. Stainless steel on the market contains an average of 68% of recycled nickel.



**NEPOUITE** (nickel silicate)  
*Népoui (New Caledonia)*

## USES



- stainless steel 70%
- alloys 16%
- nickel plating 8%
- batteries 5%
- others 1%

Source: Nickel Institute 2018

### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <https://minerals.usgs.gov/minerals/pubs/commodity/nickel/mcs-2019-nicke.pdf>
- <http://www.nickelinstitute.org>
- <https://www.eurometaux.eu/>
- <https://roskill.com/market-report/nickel/>




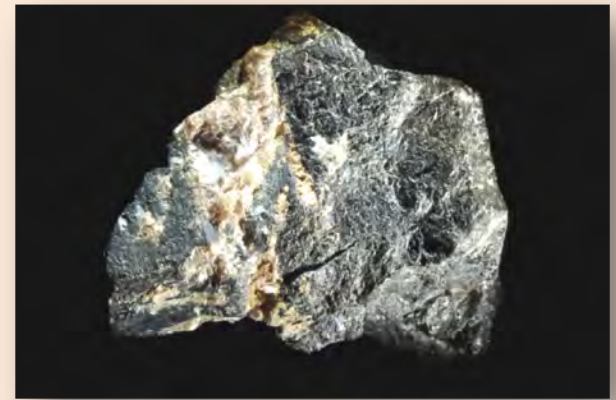
Batterie Ni-MH (Prius car)



# NIOBIUM (Nb) [Z=41]

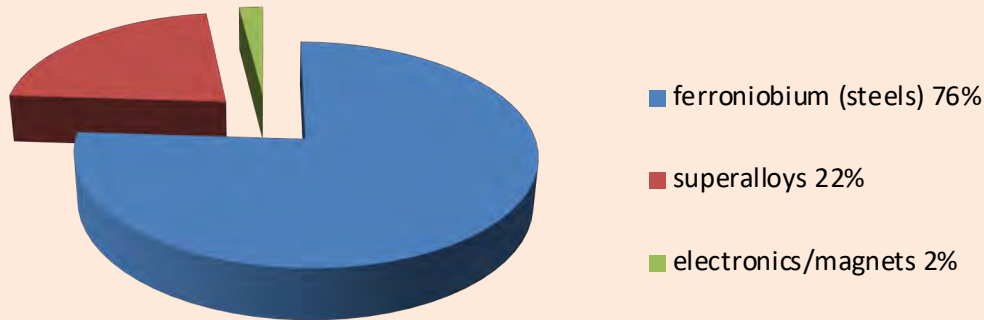
- A metal that is resistant to corrosion.
- Ductile and hard.
- A relatively rare metal.
- The EU classified it as a strategic metal in 2017.
- Found in columbite-tantalite (*coltan*), pyrochlore and euxenite.

 Niobium is recycled from steels and superconducting magnets.



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

## USES



Source: USGS



### 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  
 STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012  
<http://tanb.org/niobium>  
<https://minerals.usgs.gov/minerals/pubs/commodity/niobium/mcs-2019-niobi.pdf>  
<https://roskill.com/market-report/niobium/>

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

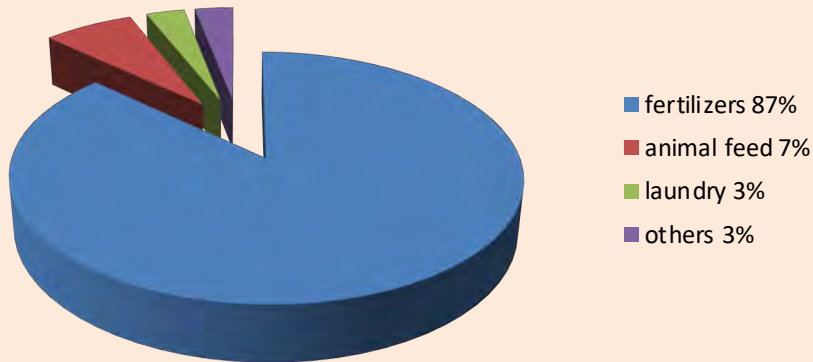
- A very reactive non-metal; it oxidises spontaneously in contact with oxygen and emits light (*phosphorescence*).
- Insoluble in water.
- An essential nutrient for plants.
- Adenosine triphosphate (ATP) is the cells' energy store.
- Phosphorus is obtained from *phosphorite* (cryptocrystalline variety of apatite).
- The EU classified *phosphorite* as a strategic rock in 2017.



PHOSPHORITE (calcium phosphate)  
Logrosán (Cáceres)

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

## PHOSPHORITE USES



Source: CRU group 2018

### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- [www.phosphor-technology.com](http://www.phosphor-technology.com)
- [https://minerals.usgs.gov/minerals/pubs/commodity/phosphate\\_rock/mcs-2019-phosp.pdf](https://minerals.usgs.gov/minerals/pubs/commodity/phosphate_rock/mcs-2019-phosp.pdf)




# PLATINUM (group)

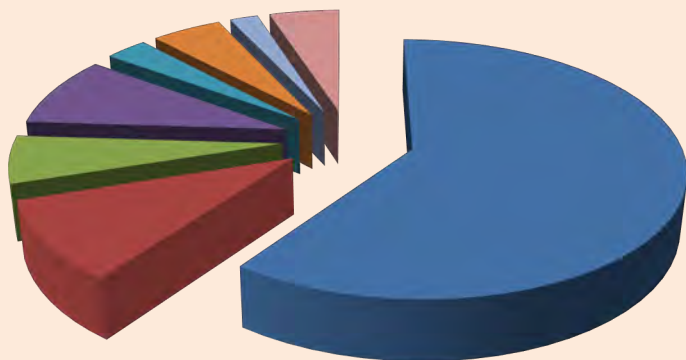
- The platinum group (PGM) is comprised of iridium, osmium, platinum, palladium, rhodium and ruthenium.
- These are noble, dense, malleable metals.
- Resistant to corrosion and high temperatures.
- The EU classified them as strategic metals in 2017.
- Very good catalysts in reactions.
- Associated with each other in nickel and copper sulfides and related minerals such as sperrylite.



PLATINUM (native)  
Chocó (Colombia)

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

## USES (platinum group)



- autocatalysts 60%
- jewellery 10%
- electrical 6%
- chemical catalysts 9%
- medicine 3%
- investment 5%
- glass 2%
- others 5%

Source: Johnson Matthey 2019



### 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
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- <https://minerals.usgs.gov/minerals/pubs/commodity/platinum/mcs-2019-plati.pdf>
- <http://ipa-news.com/index/platinum-group-metals/the-six-metals>

# 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 sylvinite and carnallite, and water from certain seas (the Dead Sea).

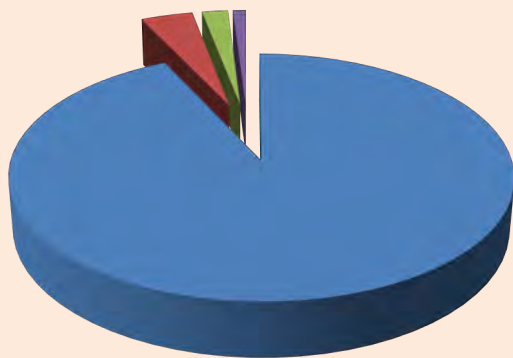


Not known to be recycled.



SILVINITE (potassium chloride)  
Sallent (Bages) Catalonia

## USES



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

Source: ICLiberia



### REFERENCES AND LINKS

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

QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCHR GmbH & Co, 2007

STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012

<http://www.icliberia.com>

<https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/mcs-2019-potas.pdf>

# 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.

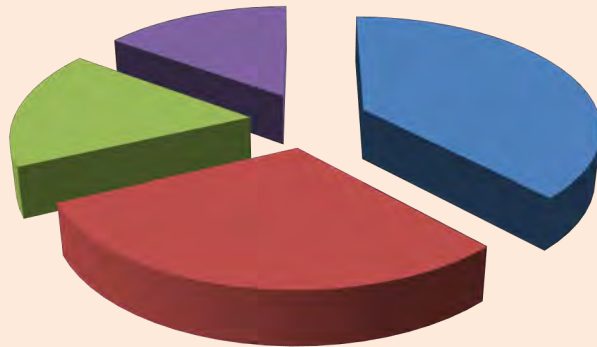


Hyaline QUARTZ (silicon oxide)  
Chamonix (France)

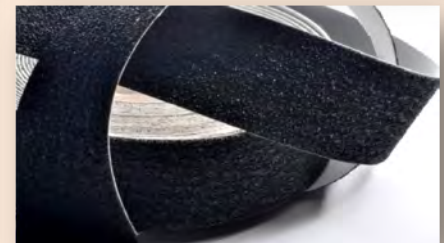


Silica sand

## USES of Silica Sand (Europe)



- glass 38%
- construction 30%
- foundry 17%
- abrasives/filters 15%



### REFERENCES AND LINKS

GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009  
 QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCHR GmbH & Co, 2007  
 STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012  
<http://www.sibelcohispania.com>  
<http://www.ima-europe.eu>



# 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 and plasma screens, low-energy light bulbs and lasers. The EU classified RARE EARTHS as a strategic metals in 2017.



The company Solvay-Rhodia recycles fluorescent bulbs due to their rare earth element content. Neodymium is recycled from old permanent magnets from hard discs.

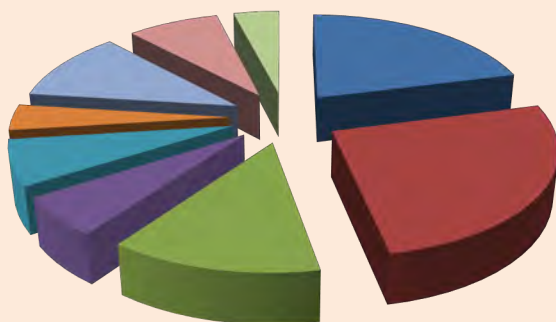


Clay impregnated with Rare Earths  
(China)



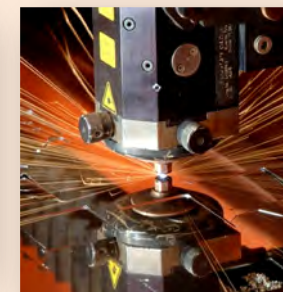
Monazite  
Minas Geraes (Brasil)

## USES



Source: Roskill 2016

- catalysts 21%
- permanent magnets 26%
- polishes 13%
- glass 6%
- phosphors 7%
- ceramics 4%
- metallurgy 11%
- batteries 8%
- others 4%




### REFERENCES AND LINKS

- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
- QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCHR GmbH & Co, 2007
- STWERTKA, Albert, *A guide of the elements*, 3rd ed. Oxford University Press, Inc. 2012
- [https://minerals.usgs.gov/minerals/pubs/commodity/rare\\_earth/mcs-2019-raree.pdf](https://minerals.usgs.gov/minerals/pubs/commodity/rare_earth/mcs-2019-raree.pdf)
- <https://roskill.com/market-report/rare-earths/>

# SEPIOLITE

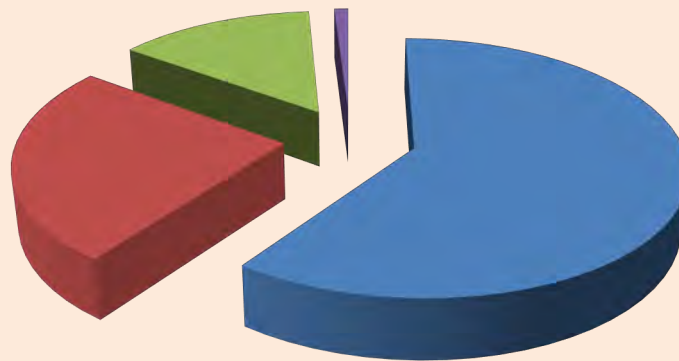
- Hydrated magnesium silicate.
- It is a special clay.
- Soft, light and porous.
- A good thermal insulator with a high capacity for absorption and adsorption.

 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

- <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).

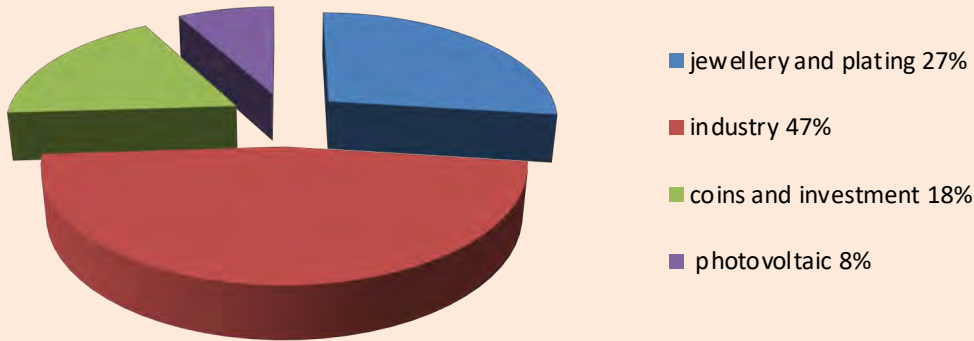


As much silver as possible is recycled. In the jewellery sector, 90% is recycled; in industry, between 40% and 50% is recycled.



SILVER (wires)  
Poblet (Conca de Barberà) Catalonia

## USES



Source: Silver Institute 2018



### REFERENCES AND LINKS

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- <https://minerals.usgs.gov/minerals/pubs/commodity/silver/mcs-2019-silve.pdf>
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- <http://www.eurometaux.eu>

# SODIUM (Na) [Z=11] and *halite (salt)*

- An alkali metal.
- Reacts strongly with water and releases H<sub>2</sub>.
- Oxidises rapidly in air.
- A basic element in human and animal diets.
- Obtained from halite.

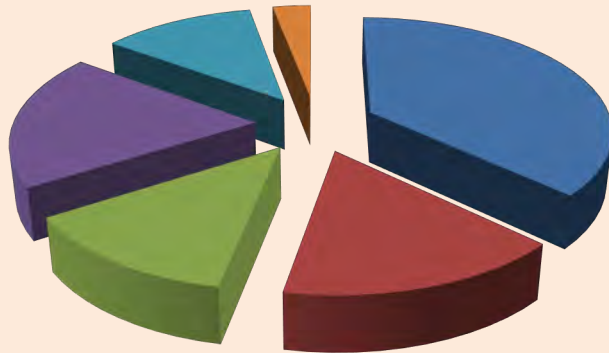


- The recycling of sodium and salt is insignificant.
- *Halite (common salt) is directly useful in food, water treatment and to prevent ice from forming on paths and roads.*



HALITE (sodium chloride)  
Súria (Bages) Catalonia

## USES of *halite*



- chlor-alkali 37%
- de-icing 16%
- food processing 13%
- soda ash 19%
- water treatment 12%
- pharmacy 3%

Source: Roskill 2017

### REFERENCES AND LINKS

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- <https://minerals.usgs.gov/minerals/pubs/commodity/salt/mcs-2019-salt.pdf>
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- <https://roskill.com/market-report/salt/>      <https://roskill.com/market-report/soda-ash/>



# TALC

- A hydrated magnesium silicate.
- An excellent mineral for filler (plastics (PP), ceramics....)
- 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.

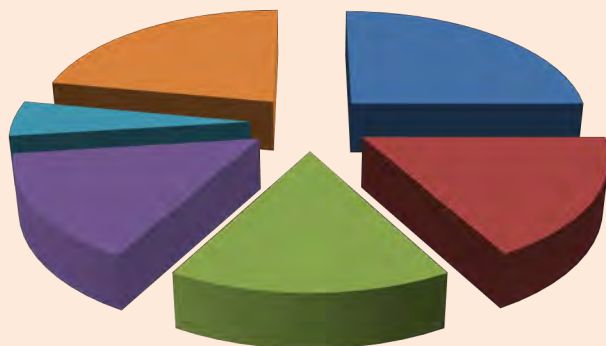


Talc is not known to be recycled, but recycling paper and plastics, we will reduce their consumption.



TALC (hidrated magnesium silicate)  
Maçanet de Cabrenys (Alt Empordà) Catalonia

## USES



- plastics/rubber 25%
- paints 17%
- paper 16%
- ceramics 15%
- cosmetics 5%
- others 22%

Source: Dr. HZ.Harraz 2017



### REFERENCES AND LINKS

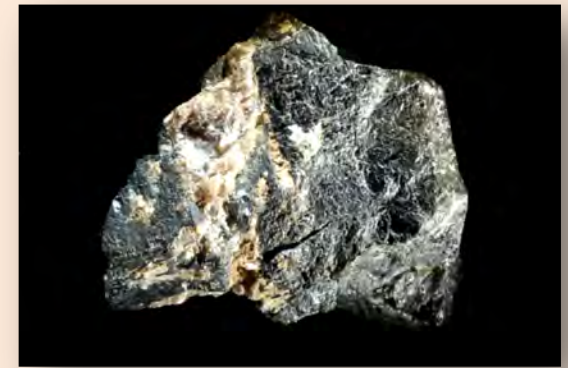
<http://www.eurotalc.eu>

<https://minerals.usgs.gov/minerals/pubs/commodity/talc/mcs-2019-talc.pdf>

<https://roskill.com/market-report/talc/>

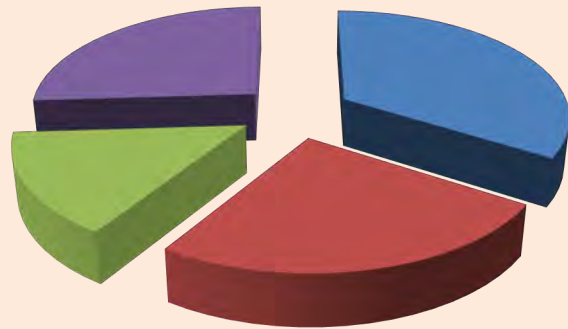
# TANTALUM (Ta) [73]

- 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.
- 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

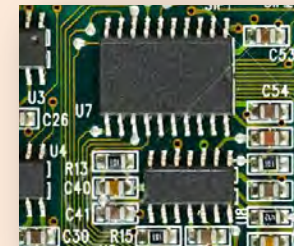


- capacitors 34%
- superalloys/carbides 25%
- sputtering targets 15%
- chemicals/others 26%

Source: Roskill 2016

### REFERENCES AND LINKS

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- QUADBECK – SEEGER, H-J, *Elements of the World*. WILEY- VCHR GmbH & Co, 2007
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- <https://roskill.com/market-report/tantalum/>



# 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.

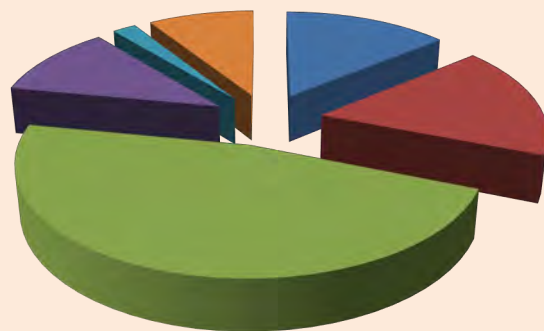


-In Europe, tin is recovered from printed circuit boards and tin cans.



CASSITERITE (tin oxide)  
Alt Empordà (Catalonia)

## USES



Source: ITA 2017

- laminates 14%
- chemical industry 17%
- welding 47%
- bronze/alloys 11%
- float glass 2%
- others 9%



### REFERENCES AND LINKS

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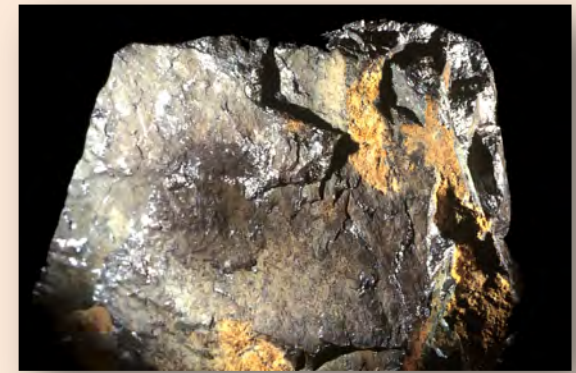
<https://minerals.usgs.gov/minerals/pubs/commodity/tin/mcs-2019-tin.pdf>

<https://roskill.com/market-report/tin/>



# 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.
- Obtained from ilmenite and rutile.

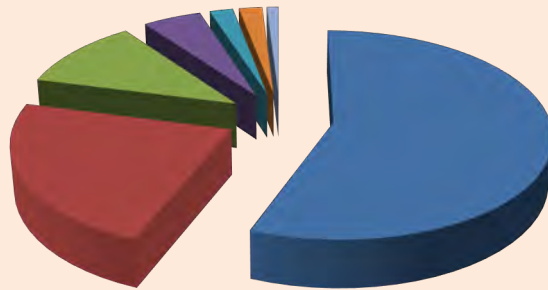


ILMENITE (titanium and iron oxide)  
Sierra de l'Albarrana (Córdoba)



Titanium is recycled from off-cuts in processes such as stamping, and from metal that has already been used.

## USES



- paints 56%
- plastics 23%
- paper 11%
- ceramics/catalysts 5%
- metallurgy 2%
- aviation 2%
- medicines/others 1%

Source: Roskill , USGS



### REFERENCES AND LINKS

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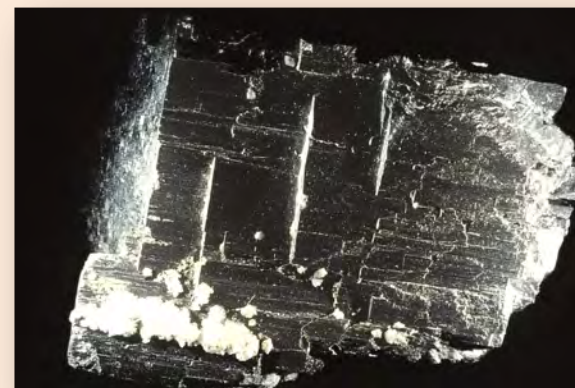


# TUNGSTEN (W) [Z=74]

- 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.

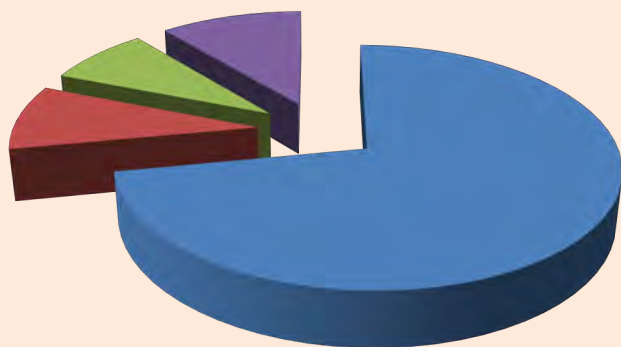


Large quantities are recycled from scrap metal and tungsten carbide (widia).



FERBERITE (iron and manganese wolframate)  
*Panasqueira (Portugal)*

## USES



- tungsten carbide (widia) 72%
- alloys/steels 9%
- filaments/electrodes 8%
- others 11%

Source: ITIA



### 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 with titanium and vanadium .



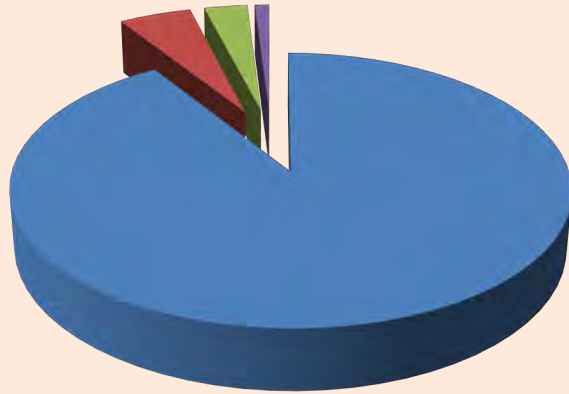
The quantity of vanadium recycled from spent chemical process catalysts is significant, and may compose as much as 40% of total vanadium catalysts.

Small percentage of vanadium steel scrap is recycled.



Magnetite with titanium and vanadium  
South-Africa

## USES



- HSLA steels 91%
- non-ferrous alloys 5%
- chemical catalysts 3%
- redox batteries 1%

Source: Roskill 2017

### REFERENCES AND LINKS

- GRAY, Theodore; MANN, Nick. *The elements*. New York, 2009
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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 (NH<sub>3</sub>).
- The main (natural) zeolites are clinoptilolite and chabazite, and the synthetics.

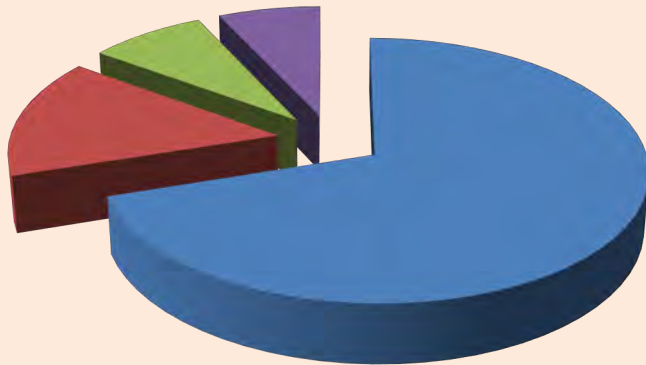


Zeolites are not known to be recycled, although they are used as drying agents, gas absorbers, water treatment agents and can be reprocessed and reused.



CHABAZITE  
Iceland

## USES



- detergents 70%
- livestock/agriculture 15%
- adsorbents 8%
- catalysts 7%

Source: H.van Bekkum / E.M. Flanigen



### REFERENCES AND LINKS

- <http://www.zeolitanatural.com/english/agricandhort.htm>
- <http://www.zeotechcorp.com>
- <https://minerals.usgs.gov/minerals/pubs/commodity/zeolites/mcs-2019-zeoli.pdf>

# ZINC (Zn) [Z=30]

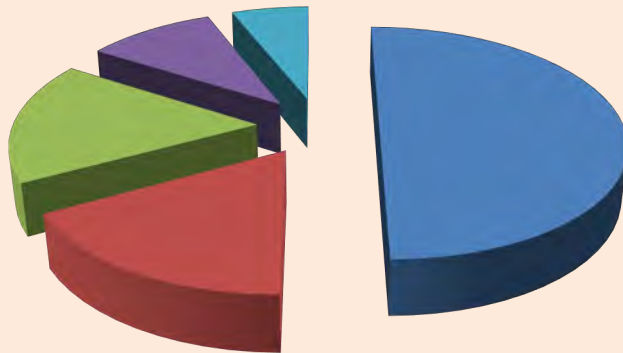
- A brittle metal.
- It has a low melting point (420oC).
- A fine layer of oxide protects the metal from further oxidation.
- Obtained mainly from sphalerite and smithsonite.

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



Caramelised SPHALERITE (zinc sulfide)  
Picos de Europa( Santander)

## USES



- galvanizing 50%
- brass&bronze 17%
- diecasting 17%
- chemical industry 10%
- rolled zinc 6%

Source: ILZSG.org

### REFERENCES AND LINKS

- GRAY, Theodore; MANN, Nick. *The elements*. New York,2009
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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) and Chemical & Engineering News (fibreglass)
- 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) and International Tin Association (tin solder)
- Zinc file: Tube-mill (tubes)