

Sources and uses of high-tech metals

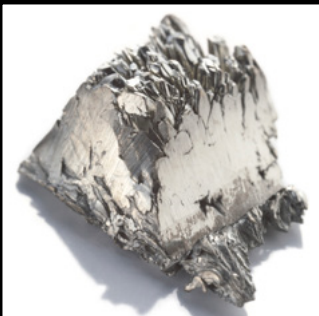
What makes some metals more special than others?

A metal is a solid material which is typically hard, shiny, malleable, fusible, and ductile, with good electrical and thermal conductivity (e.g. iron, gold, silver, aluminium and alloys such as steel).

Almost 80% of the elements listed in the periodic table are metals, but only some are considered high-tech.

The technological innovation behind the rapidly growing high-tech industry would not be possible without the unique chemical (conductivity, high melting point) and physical (strength, density and hardness) properties of particular metals – the high-tech metals. Without them, some of the high-tech products we take for granted, such as mobile phones, lithium-ion (Li-ion) batteries, satellites, and hybrid vehicles, could not have been developed.

Some of these high-tech metals are rare, in short supply or hard to refine. For these reasons, significant effort is focused on reducing the amount of these metals required for end-use applications, to lower costs and sustain the supply of raw materials into the future. New ways of using high-tech metals are constantly being developed for emerging technologies.

<p style="text-align: right; margin: 0;">21</p> <p style="font-size: 2em; font-weight: bold; margin: 0;">Sc</p> <p style="margin: 0;">SCANDIUM</p>	
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Properties and sources

Scandium is a silver-coloured metal that tarnishes in air, burns easily and dissolves in water. It also has a low density and a high melting point.

Scandium is a valuable commodity because economic deposits are extremely rare. Current global supply is mainly from secondary sources, such as mineral waste stockpiles, or as a by-product from other mineral processing operations.

Recently a number of large, high-grade scandium oxide deposits have been discovered in central New South Wales and northeast Queensland. NSW already has scandium projects that include areas which have undergone very little exploration.

Uses

Scandium is mostly used in alloys with aluminium for the aerospace industry, as it has excellent strength and is lightweight.

<p style="text-align: right; margin: 0;">3</p> <p style="font-size: 2em; font-weight: bold; margin: 0;">Li</p> <p style="margin: 0;">LITHIUM</p>	
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Properties and sources

Lithium is a soft, silver-coloured metal that reacts vigorously with water. Nearly all types of igneous rocks contain a small amount of lithium-bearing minerals. Mineral-rich springs and brines can also contain lithium.

Mining operations in Australia (43%), Chile (33%), and Argentina (13%) accounted for the majority of world lithium production in 2017 (United States Geological Survey (USGS) 2018a).

Uses

Rechargeable (Li-ion) batteries are the main use for lithium. Li-ion batteries, such as in your smartphone, typically contain a lithium manganese oxide liquid gel. Lithium is also used in aluminium alloys for the aerospace and transport industries, and alloyed with magnesium and aluminium in military armour plating on tanks and ships.



Properties and sources

Cobalt is a distinctive blue and lustrous metal. Like iron, it is magnetic, and used to make powerful magnets in aluminium–nickel alloys. It has a high melting point and is resistant to corrosion.

Cobalt is reasonably abundant in Earth’s crust and is often found in copper and nickel deposits, and in manganese nodules on deep-sea ocean floors (Atlantic, Indian and Pacific oceans).

In 2017, the Democratic Republic of Congo (DRC) produced about 58% of the world’s cobalt. Australia was the world’s 4th largest cobalt producer (4.5%), with about 17% of the global cobalt reserves (USGS 2018b). NSW has several advanced cobalt projects near Nyngan, Fifield, Port Macquarie, Goulburn, Thuddungra and Broken Hill.

Uses

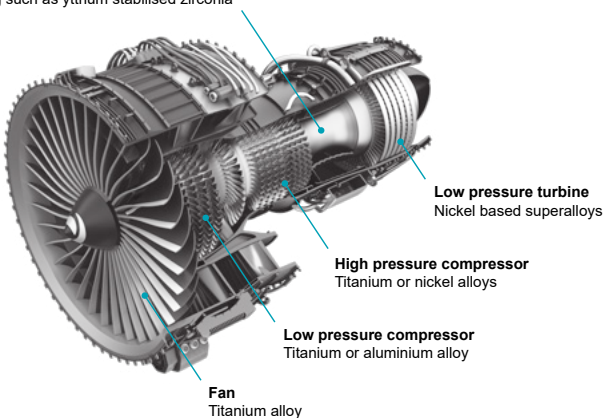
The main uses for cobalt are in magnets and metal-ion batteries. Cobalt was the first cathode material used for commercial lithium-ion batteries. Due to high cobalt prices, manufacturers often mix cobalt with nickel, manganese and aluminium to create powerful cathodes that are cheaper and can have better performance than pure cobalt. Despite this substitution, cobalt typically comprises between 5–60% of the cathode by weight, with approximately 50% of the cobalt produced globally used in rechargeable batteries.

A typical smartphone battery contains 16 grams (g) of cobalt and an electric vehicle battery uses up to 15 kilograms (kg) of cobalt (https://s1.q4cdn.com/337451660/files/doc_downloads/factsheet/2017/170712-Cobalt-Fact-Sheet.pdf).

Cobalt-bearing metal alloys are also used in gas turbine generators and jet turbines due to their strength and high temperature resilience properties. Paints, enamels and pottery glazes also use cobalt, due to its vivid blue colour. It is also used in a range of medical and scientific applications.

Jet engine

Combustion chamber and high pressure turbine
Nickel based superalloys with a thermal barrier coating such as yttrium stabilised zirconia



Rare earth elements (REEs) are a diverse group of 17 metals, which include the lanthanide series of elements, scandium (Sc) and yttrium (Y). The lanthanides include lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu).

Properties and sources

REEs are a group of metals which have unique chemical, nuclear, electrical, magnetic and luminescent properties.

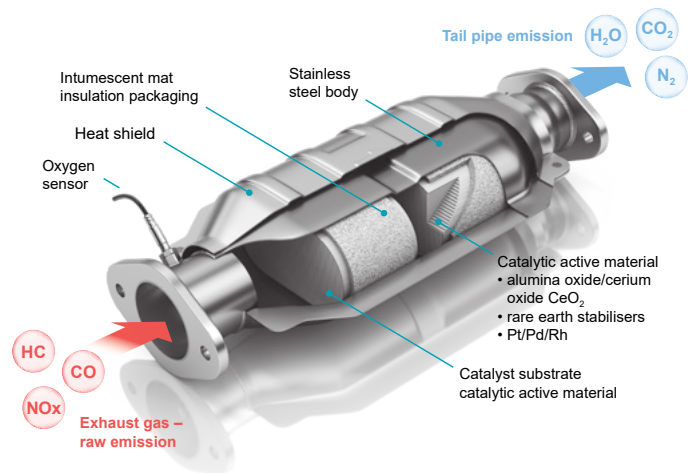
REEs are not as rare as their name implies. However, they do not generally accumulate in rich ores so they are often difficult to mine and process. In 2017, China produced approximately 81% of the global REE supply, with Australia producing 15% – making it the second largest supplier (USGS 2018d).

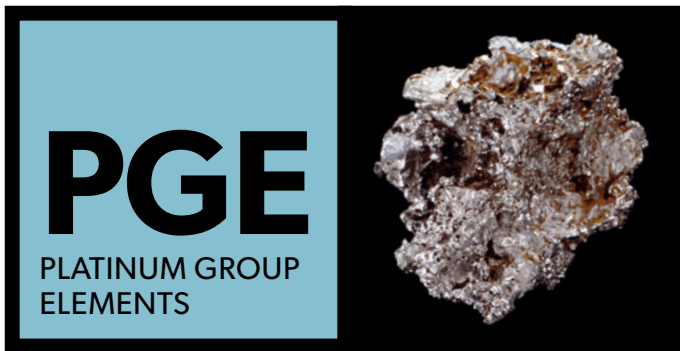
REEs occur across a range of geological settings and provinces in NSW, including granites, volcanic rocks and the extensive heavy mineral sand deposits in the Murray Basin.

Uses

REEs are essential for high performance optics (lenses, fibre optics) and lasers. They are also used in powerful magnets, which are critical in many electric motors and generators including servo motors in power tools, electricity generators in wind turbines, and drive motors in electric vehicles. REEs are also very important in batteries and catalytic converters to reduce motor vehicle emissions.

Catalytic converter





The platinum group elements (PGE) are a group of six precious metals grouped together in the periodic table. The PGEs include platinum (Pt), palladium (Pd), iridium (Ir), osmium (Os), rhodium (Rh) and ruthenium (Ru).

Properties and sources

Of the six PGEs, the most commercially significant are platinum, palladium and, to a lesser degree, rhodium. The properties which make these elements commercially important include their resistance to corrosion and oxidation, high-melting points, electrical conductivity and catalytic activity. They are used in the chemical, electrical, electronic, glass and motor vehicle industries (Geoscience Australia 2013).

PGEs are very rare, with the upper crust of Earth containing only about 0.0005 parts per million of platinum, making these metals highly sought after and valuable. In 2017, approximately 200 000 tonnes (t) of both platinum and palladium were produced worldwide, mainly from Russia and South Africa (USGS 2018c).

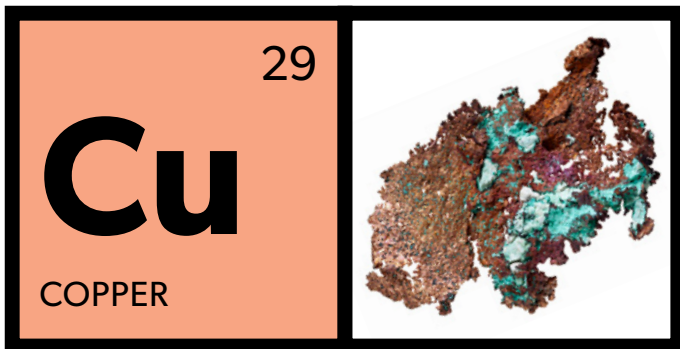
Uses

Since 1979, the car industry has been the main consumer of PGEs, with over 40% of the world's platinum used in catalytic converters, resulting from efforts to control emissions and to improve fuel efficiency.

PGEs are also used in high-tech alloys for specialist industrial and electronic applications such as computer hard drives, ceramic capacitors, integrated circuits, glass manufacturing, jewellery and laboratory equipment.



Computer hard disk.



A 1.5 megawatts (MW) wind turbine requires approximately 1800 kg of copper (Copper Development Association Inc. 2018b). The recently approved Liverpool Range Wind Farm in NSW will be Australia's largest wind farm. Potentially, it will have up to 267 turbines, generate over 1000 MW of electricity, and contain over 1000 t of copper. Clearly, copper will be just as important in the high-tech, environmentally sustainable future as it has been for the last 10 000 years.

Most of the gold produced is used for jewellery (52%) and as currency (25%), but it is also essential for making electronic components and connections which are extremely reliable and efficient. Gold is commonly used as a very thin coating over copper circuitry components to prevent corrosion or oxidation and maximise performance. In 2017, technological applications used 332.8 t of gold, accounting for approximately 10.6% of the amount of gold produced (<https://www.gold.org/research/gold-demand-trends/gold-demand-trends-full-year-2017>).

A mobile phone contains on average 50 milligrams of gold. With an estimated 7 billion mobile phones worldwide, that adds up to 350 t of gold contained in these devices (Straterra 2018).

Emerging uses for gold nano-particles include catalysts in industrial processes; pollution reduction in air and water; fuel cells and lithium-air batteries; and solar cells. Gold is also vital in medical applications such as new diagnostic tools and treatments.



Refined copper and gold metal are the 'unsung heroes' that underpin electronic components and circuitry in a wide range of everyday and cutting-edge technological applications. Copper, in particular, remains a relatively cheap but essential raw material for electronic applications at microscale (microcircuits) to megascale (energy infrastructure and power grids).

Properties and sources

Copper was first used in coins and ornaments around 8000 B.C. About 5500 B.C., copper tools helped civilisation emerge from the Stone Age. The discovery of bronze (copper-tin alloy) in 3000 B.C. marked the start of the Bronze Age. Copper is still an important metal in high-tech applications as it is easily stretched, molded and shaped, is resistant to corrosion, and is an efficient conductor of heat and electricity.

Gold was first smelted in Ancient Egypt 5600 years ago to decorate tombs and temples. Since then, it has become the most widely used mineral due to its diverse properties. Apart from its wonderful colour and lustre, gold can be melted, recast and beaten into atom-thin sheets through to wire thread, is a highly reliable and durable electrical conductor, and is resistant to rust and corrosion.

In 2017, approximately 20 million tonnes of copper (USGS 2018e) and 3150 t of gold (USGS 2018f) were produced globally.

Uses

Copper and copper alloys are widely used in building construction, electrical and electronic products, transportation equipment, consumer and general products, and industrial machinery and equipment. A petrol car uses about 20 kg of copper (mostly in the 1.5 kilometres of wiring). In contrast, a hybrid car uses about 40 kg of copper and a fully electric car uses about 80 kg of copper. A single battery electric bus uses about 370 kg of copper (Copper Development Association Inc. 2018a).



Recycling high-tech and associated metals – challenges and opportunities

Some high-tech metals, in particular copper and gold, are relatively straightforward to recycle and retain their properties during recycling. Roughly 25% of all copper and gold used today is from recycling. For both these metals, recycling can be a cost-effective alternative to mining.

Although platinum and palladium can be difficult to recycle due to their scarcity (among the rarest metals on Earth), very high value and necessity in many modern technologies, recycling provides a significant proportion of the world's total supply, helping to close the gap between world mine production and consumption.



Apple's disassembly robot Daisy can dismantle up to 200 iPhones per hour. Image courtesy of Apple.

For metals such as lithium, scandium and REEs, less than 1% of the metal used is recycled. This is a major challenge for recycling lithium-ion batteries, as currently less than 5% of batteries are recycled. Of the batteries which are recycled, it is profitable to recover the copper, nickel and cobalt but not the lithium. New technologies need to be developed to make lithium recovery viable. This is particularly important

given the expected growth in demand for batteries for electric cars.

While there are environmental, economic and social benefits to recycling, current recycling rates are also low for most other high-tech metals. Some of the technical barriers to recycling (Dominish et al. 2017) include –

- products are not designed for disassembly, remanufacturing, repair or recycling
- products are not designed to be durable, which limits the ability to reuse
- products are more complex, with increasing numbers and mixes of materials, making them harder to recycle
- rapid technological development has led to demand for new materials, limiting the potential to remanufacture new products using recycled materials.

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