Essential Minerals for the Green Revolution – 3 Rare Earth Elements
Vital components in modern technology

Humans have used metals such as copper, iron, lead, zinc and tin for several thousand years. In recent decades many less well-known metals have become very important in a wide variety of products, ranging from mobile phones to electric cars.

Show pupils the photographs and ask if they can suggest which group of "new" metals now form important constituents, even though the quantities may be relatively minor. Providing them with a copy of the Periodic Table might help some to decide on an appropriate group of elements.

Mobile phone

Catalytic converter for "cracking" oil *Creative Commons Attribution-ShareAlike License 3.0;*

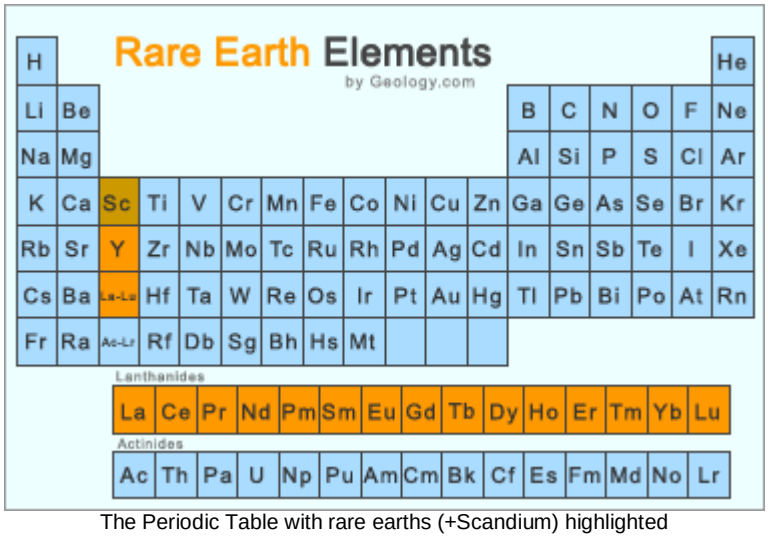
Binoculars

Low energy light bulb

MRI scanner (*Image by Michal Jarmoluk from Pixabay*)

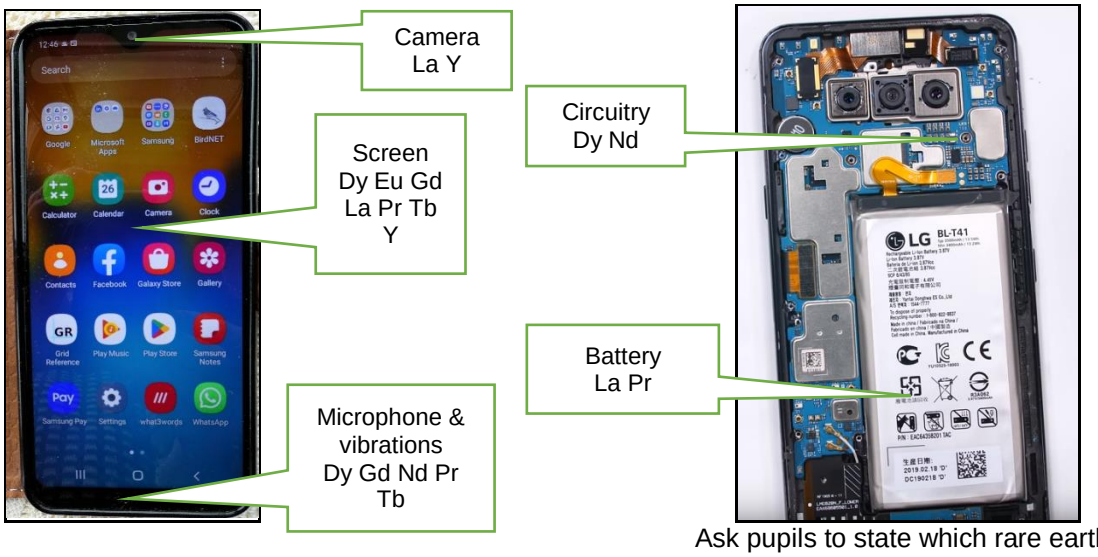
Wind turbine (*Creative Commons Attribution-ShareAlike License 3.0)*

(*Pupils may well suggest valid answers, but may need prompting to say "rare earth elements" as these are not generally well known. The version of the Periodic Table below highlights the rare earths.*



The Periodic Table with rare earths (+Scandium) highlighted

Show pupils the diagrams below and ask them to state how many different rare earth elements are used in a mobile phone (*8)*



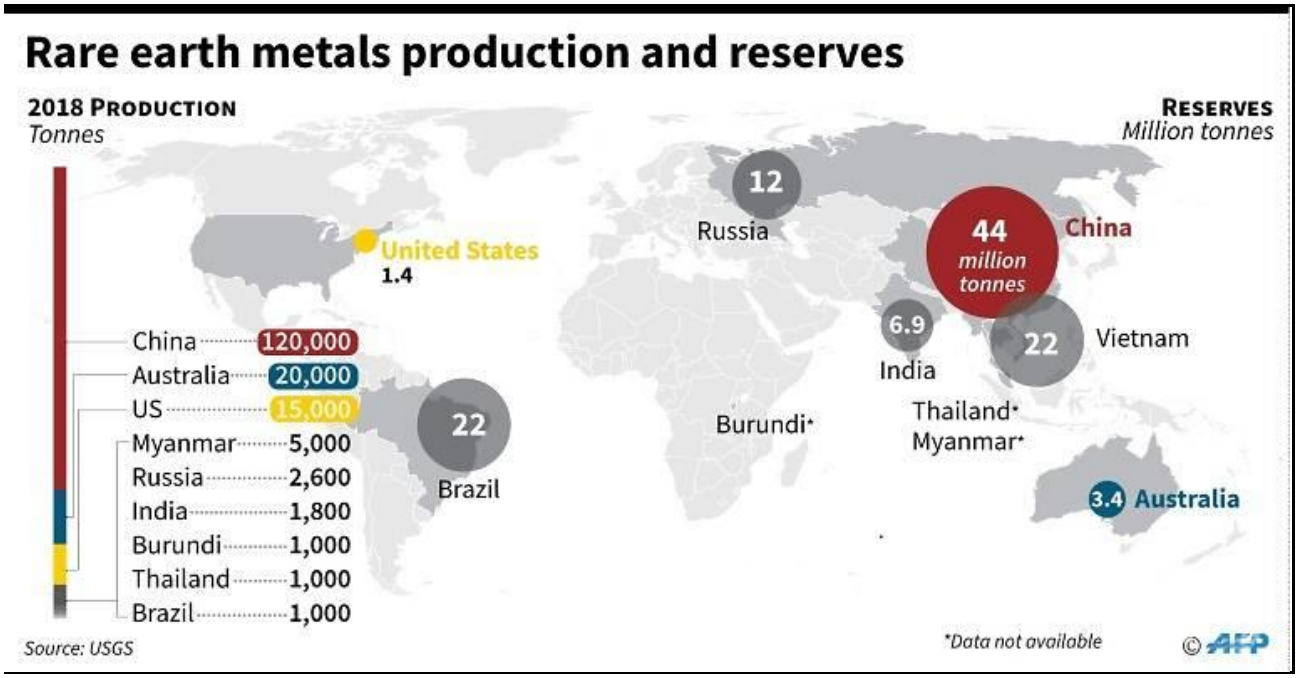
Ask why it is difficult to recycle the rare earths when a mobile phone is scrapped (*Rare earths are used in very small quantities. The properties of the rare earths are very similar to each other*).

Ask pupils to state which rare earth elements are used in each of the applications shown in the photos on page 1 and to find examples of other uses of the rare earths. The table below provides a selection of just some of these many uses. (Scandium and Yttrium are found with rare earths although they are not themselves rare earth elements)

Symbol	Name	Some uses
Sc	Scandium	alloys
Y	Yttrium	alloys, lenses, low energy light bulbs
La	Lanthanum	lenses, catalytic cracking of oil
Ce	Cerium	catalytic cracking of oil, polishing (cerium oxide used for polishing)
Pr	Praseodymium	magnets, lasers, lenses
Nd	Neodymium	magnets, lenses
Pm	Promethium	nuclear batteries (There are no stable isotopes of Pm)
Sm	Samarium	magnets, control rods in nuclear reactors
Eu	Europium	lasers
Gd	Gadolinium	catalytic cracking of oil, MRI scanners
Tb	Terbium	magnets, energy efficient light tubes
Dy	Dysprosium	magnets
Ho	Holmium	magnets

Er	Erbium	lasers, fibre optics
Tm	Thulium	lasers, X-ray machines
Yb	Ytterbium	lasers, monitoring earthquakes
Lu	Lutetium	LED lights

Rare earth elements and some of their uses



Rare earth metals production and reserves 2018

The map shows the main countries with reserves of rare earths in 2018.

a) Suggest advantages and disadvantages of this distribution for your own country. China was the largest producer in 2018, followed by Australia and the USA, but Chinese companies own some of the mines in countries beyond China itself. A new major deposit of rare earths in the north of Sweden was announced in late 2022. (*Answers may cover uneven distribution, transport distances and difficulties, political instability or war*).

b) In 2022 production figures had changed dramatically. The top 9 countries are shown in the table below, with production for 2022 in tonnes:

Country	Production of rare earths in tonnes
China	210,000
USA	43,000
Australia	18,000
Myanmar (Burma)	12,000
Thailand	7,100
Vietnam	4,300
India	2,900
Russia	2,600
Madagascar	960

Rare earth metals production 2022

Compare the quantities of rare earth metals produced in 2022 with those for 2018 and suggest reasons for the differences.
(*The overall tonnages from the top 9 countries have almost doubled in the 4 years, reflecting the rapid growth in technologies which require rare earths, notably in renewable energy, with China being a major manufacturer. The USA reopened a closed mine in California. Australia is developing new mines, now coming on stream. Vietnam is developing its own renewable energy industries. Russia's output has been affected by its invasion of Ukraine. Madagascar has very large reserves, which may be developed in the future*).

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The back up

Title: Critical Minerals – 3 Rare Earth Elements

Subtitle: Vital components in modern technology

Topic: Investigating the uses of rare earth elements as minor, but vital components in a wide range of industrial products.

Age range of pupils: 12 years upwards

Time needed to complete activity: 20 minutes, plus time for individual research

Pupil learning outcomes: Pupils can:

- describe the importance of rare earth elements in modern society;
- explain why rare earth elements are not uncommon in the Earth's crust but are seldom concentrated into ore deposits;
- explain why rare earth elements are difficult to recover during recycling of old equipment;

- describe the problems associated with uneven distribution of rare earth elements across the world.

Context: This activity could be used in a lesson on the need to identify and exploit rare earth minerals in vital applications in many different fields, ranging from optics to energy saving devices and medical equipment. They are particularly important as catalysts in industrial processes and in the manufacture of strong magnets.

Following up the activity:
Carry out a web search for more information and for staying up to date, since the situation is changing rapidly.

Underlying principles:
- The rare earth elements are all silvery dense metals with closely related properties.
- Rare earth minerals were first discovered in Sweden in 1787 and many of the names reflect their Scandinavian occurrence.
- Rare earth minerals are not as rare as the name would suggest: e.g. cerium at 68 parts per million in the Earth's crust is rather more abundant than copper.
- Deposits are widely dispersed and are seldom concentrated sufficiently to form a viable ore deposit.
- Primary sources of rare earth minerals include granite and pegmatite masses, but important deposits are also found in beach sands and in clays produced by weathering of the primary sources, e.g. China.
- Rare earth minerals have been found in marine deposits at hydrothermal vents: these could become important sources if international law ever allows exploitation.
- Recycling of rare earth elements is becoming more common.

Thinking skill development:
Finding a pattern in the properties and uses of rare earth elements involves construction. Metacognition is involved when problems in the distribution of ores are discussed. Applying thinking to new contexts is a bridging skill.

Resource list:
- access to the photographs in this activity, or the equivalent on the web

Useful links: Top 10 Countries for Rare Earth Metal Production (Updated 2023) (investingnews.com)
https://www.compoundchem.com/2014/02/19/the-chemical-elements-of-a-smartphone/
and for a Top Trumps game, see SoS MinErals – GeoBus (st-andrews.ac.uk)

Source: Written by Peter Kennett of the Earthlearningidea team

Note: This activity was as accurate as possible in spring 2023. Rapid developments are taking place in the technology of low and renewable energy.

Essential Minerals for the Green Revolution

Earthlearningidea has compiled a series of activities on the minerals which are essential if modern technology is to be able to reduce the World's carbon footprint. Some are regarded as "critical" minerals and many of them are relatively "new" in terms of needing to be exploited.
This table will be updated as fresh activities are added.
All titles begin with: Essential Minerals for the Green Revolution…

Mineral	Title
Lithium	1 Lithium: an element which is pulling more than its weight in the world
Copper	2 Copper: an element for which the demand is increasing rapidly
Rare Earths	3 Rare Earth Elements: vital components in modern technology
Graphite	4 Graphite: from a pencil to the electric car!
Cobalt	5 Cobalt: mined by children
Tin, Tungsten, Tantalum	6 "The Three Ts": Tin, Tungsten and Tantalum
Gold	7 Gold: an essential mineral - or is it?
Critical minerals	8 Critical Minerals: Essential mineral - critical mineral: what is the difference?