62 Endangered Elements

By Chris Patrick

TIGERS, GIANT PANDAS, POLAR bears—you've heard of endangered animals. But did you know that elements on the Periodic Table can be endangered, too?

Although these elements are not in danger of going extinct—chemical elements are essentially indestructible, and atoms generally last forever—the useful supplies of some 62 elements are running out. Also, one day, these elements may be so inaccessible that it might not make sense to harvest them anymore.

The Periodic Table of Endangered Elements is exactly like the normal Periodic Table, except that the squares representing certain elements are color-coded yellow, orange, or red (Fig. 1). These colored squares are the 62 endangered elements.

Just like animals, there are different levels of risk for the endangered elements. The color of an element on the Periodic Table of Endangered Elements indicates how high the element is at risk of running out.

Ten elements are at serious risk of running out in the next 100 years. These elements—helium, zinc, gallium, indium, tellurium, hafnium, europium, terbium, dysprosium, and ytterbium—are shaded red in Fig. 1. The threat of running out of 13 other elements has increased recently, because these elements are being used more and more. These elements are red and yellow in Fig. 1. Also, 39 other elements are predicted to be at risk in the future—these elements are shaded orange in Fig. 1.

Endangered elements at every level of risk have unique properties. We depend on these elements and their unique properties because we use products that contain them every day. If we run out of the reserves of endangered elements, we might not be able to make the products that contain them, including the smartphone in your pocket.

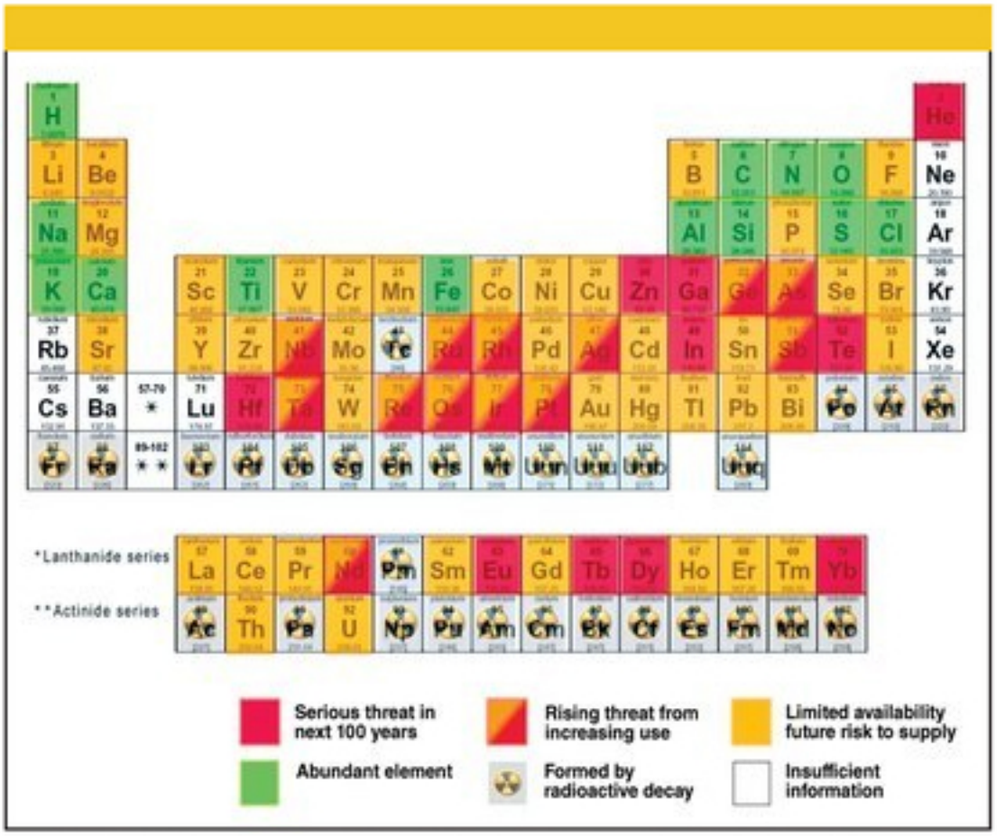

Figure 1. This version of the Periodic Table of Endangered Elements, developed by Mike Pitts, a sustainability manager with the Chemistry Innovation Transfer Network, separates the endangered elements into three categories, color-coded red, orange, and yellow.

SOURCE: HTTPS://CHEM.AS.UKY.EDU/DAYWOOD/SUSTAINABILITY-ENDANGERED-ELEMENTS

You need indium to Instagram

Indium
49
In
114.82

Your typical smartphone contains 40 elements. Among these 40 elements is indium. Although you might not have heard of it, indium is critical to the function of your phone.

On the Periodic Table of Endangered Elements, indium is in the red. It is a severely endangered element. **We may have less than two decades' worth left.**

Indium is a metal with unique properties that make it ideal for manufacturing touchscreens. Manufacturers combine indium with tin and oxygen to make a compound called indium tin oxide. **Indium tin oxide is a mixture of indium(III) oxide (In_2O_3) (typically 90% by weight) and tin(IV) oxide (SnO_2) (typically 10% by weight).** Manufacturers can make a regular sheet of glass into a touchscreen by coating it with indium tin oxide, which is transparent and highly conductive to electricity.

Indium is relatively rare; its abundance in the Earth's crust is estimated to be around 0.1 parts per million. So, with less indium readily available and more technology made worldwide, the price of indium has risen. Eventually, it may be too expensive to use in touchscreens. That means we might need to find an alternative, especially given that the U.S. Geological Survey says we will run out of extractable indium in less than 20 years.

In addition to finding alternatives, another solution could be recycling indium by extracting it from used and discarded devices. Currently, less than 1% of indium is recycled. If we can figure out a way to extract it from castaway phones and other technology, we may be able to stretch reserves longer than 20 years.

Although indium reserves are running low, one thing that is important to remember is that the total amount of indium on Earth is not being diminished—it is just being spread all around the globe. ***"Instead of all the indium being present where we dig to harvest indium, it's in cell phones scattered all over the Earth,"*** says David Atwood, a chemistry professor at the University of Kentucky, Lexington, Ky.

This makes sense if we consider the law of conservation of matter, which states that matter is neither created nor destroyed. None of the indium is destroyed; it is just dispersed, making it harder to retrieve for future use. **So, unlike animals, endangered elements are not in danger of actually going extinct on Earth.**

From your birthday party to outer space

Helium
2
He
4.003

A few days after your birthday party, a balloon that once floated in the air falls to the floor, where it shrinks and shrivels. That's because helium, the light, colorless, and odorless gas that kept the balloon aloft, has leaked out of the balloon. Helium also escapes through cracks in your house into the Earth's atmosphere.

Once it enters the Earth's atmosphere, helium is basically impossible to recover. In principle, we could purify this element from the air. But the total amount of helium in the air is so small that it is not technologically feasible to recover it. Also, even if the technology were developed, it probably would not be economical.

Helium may be the second-most abundant element in the universe, but here on Earth, it is rare. Although you can buy a helium balloon from the party store for just a few dollars, helium—like indium—is a severely endangered element. The U.S. National Helium Reserve, located in Amarillo, Texas, is the largest helium reserve in the world. But based on our current rate of helium consumption, it is estimated that only 25 years' worth of helium is left in the national reserve.

Helium is produced underground by the decay of thorium and uranium, two radioactive elements, as follows:

$$^{232}_{90}\text{Th} \rightarrow {}^{228}_{88}\text{Ra} + {}^{4}_{2}\text{He}$$

$$^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He}$$

$^{4}_{2}\text{He}$ are the nuclei of helium atoms, also called alpha particles. Each consists of two protons and two neutrons; when an alpha particle combines with two electrons, a helium atom is born.

So as we use helium, more is being produced, but not fast enough. "Helium is being

Helium, continues on the next page

Helium, continued from p. 17

regenerated, but the time frame is beyond anything that makes sense to us humans," says David Atwood, a chemistry professor at the University of Kentucky, Lexington, Ky. "Right now, we are using up concentrated helium that took millions of years to make."

We cannot wait millions of years for more radioactive elements to decay and replenish the usable supplies of helium, which, in addition to birthday balloons, is used in welding and medical imaging. When welders use electricity to melt and fuse two pieces of metal, they also use a "shielding gas," an inert (or inactive) gas—like helium—that shields the vulnerable, molten metal from contamination by oxygen and water vapor in the atmosphere. At hospitals, magnetic resonance

imaging (MRI) machines take pictures of the inside of organs, tissues, and tumors using magnetic fields. They need liquid helium to cool the special magnets that make these fields in the machine.

We might be able to extend the lifetime of this helium reserve if we set up a way to recycle the element. But because helium is cheap, recycling it is not yet cost effective.

Phosphorus feeds our food

Phosphorus
15
P
30.974

Indium, helium—these two elements are important, but without phosphorus, you would not exist. No living beings would. Phosphorus is an ingredient of DNA, the genetic blueprints inside every one of your cells. It is also an important component of your teeth and bones, and plants need it to grow.

The most important product containing phosphorus is the fertilizer used to grow crops. Plants' roots take up phosphorus from water in soil. **But phosphorus compounds are not very soluble in water, so most soils have less phosphorus available than plants need.** That is why modern agriculture relies on phosphorus-containing fertilizers.

As the world population grows and needs more food, the demand for phosphorus is also rising. We mine phosphorus from rock, but scientists estimate that in 30 to 40 years there will not be enough phosphorus left in reserves to meet agricultural demand. Not enough phosphorus means not enough fertilizer, which means not enough food.

That is why phosphorus is shaded yellow on the Periodic Table of Endangered elements. Its reserves are not quite as depleted as those of indium and helium, but it is in limited supply. Although there is a limited supply of phosphorus in reserves, there is still the same amount of phosphorus on Earth. Just like indium, the phosphorus that was once found in rocks is now more spread around. We cannot keep mining for it in the same spots, but we may be able to recycle the phosphorus that we have already used.

Excess phosphorus from crop fertilizers that was not taken up by plant crops ends up in the runoff that flows out of crop fields and into nearby bodies of water. We, and other animals, also excrete phosphorus in our waste, which also eventually finds its way to water. Some people wonder if we might be able to extract phosphorus from water and waste to re-use it in agriculture. Will we figure out how to recycle phosphorus before demand exceeds supply?

Beyond recycling

Phosphorus is irreplaceable in living systems. No other element can serve as a substitute. The only way to ensure our supply doesn't run out is to figure out how to recycle it, or curb usage. But for other endangered elements, there are solutions beyond just recycling.

Depending on what it's being used for, different elements can replace **helium**. Helium can be swapped with hydrogen in balloons, but hydrogen—which isn't on the endangered list—isn't exactly an ideal addition to a birthday party, because it's highly flammable. This means candles, or any other fire, must be kept far away. In some MRI machines, liquid nitrogen can do the job of liquid helium. Argon can take the place of helium in welding. Increasing the price of helium may also encourage more efficient use overall.

Like helium, there are alternatives to the **indium tin oxide** used in smartphones and other touchscreen devices. Researchers are figuring out how to make the same technology with more abundant alternatives, such as carbon. Others are trying to make indium tin oxide with less indium. However, there are still challenges associated with each alternative.

In addition to looking for alternatives, another solution is longer-lasting products. Making more durable, longer-lasting products may allow endangered element reserves to last longer. If your phone, for example, can survive screen-cracking falls or a swim in the toilet, you won't have to buy another, keeping just that little bit of indium in reserves instead of in your pocket. CM

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SHUTTERSTOCK

Undeserved Reputation?

FLUORIDE & WATER FLUORIDATION

$Ca_{10}(PO_4)_6(OH)_2$

HYDROXYAPATITE

Main constituent of tooth enamel, which can be dissolved in acidic conditions. Ions lost can be replaced by those in saliva; cavities form if the replacement rate is lower than the rate of loss.

$Ca_{10}(PO_4)_6F_2$

FLUORAPATITE

Fluoride ions can replace hydroxide ions in hydroxyapatite, forming fluorapatite, which is stronger and more resistant to acidic conditions. As a result, it greatly reduces cavity formation rate.

Countries with artificial fluoridation programs

35 COUNTRIES 377 MILLION PEOPLE

An additional 28 countries supply naturally fluoridated water to more than 280 million people. Some countries do not fluoridate water; instead, they fluoridate table salt (such as Germany, Switzerland, and France) and/or milk (Bulgaria, Chile, and others).

Fluoridated toothpastes have also contributed to declining tooth decay rates worldwide.

Skeletal fluorosis may occur in people who have ingested 10-20 mg of fluoride per day for 20 years.

1 mg OF FLUORIDE PER LITER

RDA OF 3 LITERS = 3 mg PER DAY

1450 mg OF FLUORIDE PER LITER

BRUSHING TWICE = 0.4mg PER DAY

Significantly below 10-20 mg per day.

Tea actually contains more fluoride than drinking water, in the range of 1.0-2.0 mg per liter. Even factoring this in, you'd still be below the 10-20 mg per day range.

FACTS ABOUT FLUORIDATION

1. **Fluoridation reduces tooth decay**
   Fluoridation is estimated by consideration of a number of studies to reduce tooth decay by 29%. It's effective in both children and adults.
2. **Fluoridation does not cause cancer**
   There is no statistically significant link between the levels of fluoride in artificially fluoridated supplies and cancer, IQ, or Down syndrome.
3. **Fluoridation can cause mild fluorosis**
   Mild fluorosis can usually only be spotted by a dentist. It doesn't cause pain or affect the health or function of the teeth.
4. **Water naturally contains fluoride**
   Fluoride is in a majority of natural water supplies at some level and also in bottled water. It's just not always at the optimal level of 1 mg/L.