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# 90 Elements that make up everything – Support notes

UNESCO has proclaimed 2019 as the International Year of the Periodic Table. The European Chemical Society has designed a new kind of Periodic Table.

**The Periodic Table** that we usually use is one developed by Dmitri Mendeleev and published in 1869 (150 years ago).

- It orders the elements in groups where each element has similar properties and in rows where different shells of electrons are being filled.
- The elements appear in order of their atomic number (number of protons in the nucleus),
- Mendeleev based his Table on the 61 elements known at that time but had to leave some gaps. These elements (gallium, scandium and germanium) were subsequently discovered and had the properties that Mendeleev predicted for them
- **Much more detail and videos concerning all the different elements can be found at** [Periodic Table of Videos][i]

**The 90 natural elements that make everything** (and the do really make EVERYTHING) has been drawn so that the area occupied by each element gives an indication of the amount of that element in the earth's crust and atmosphere.

## Areas

- The areas relate to numbers of atoms of each element on a logarithmic scale.[ii]
- There are actually 92 elements in the chart. Two of these elements, technetium (Tc) and promethium (Pm), which are coloured white, are not included in the 90. These are radioactive elements that are mostly synthetic, although very small amounts of Tc do occur naturally.
  - Technetium (Tc) is very important for imaging soft tissue such as the heart and it is made through radioactive decay of a longer-lived isotope of Molybdenum (Mo). The formed isotope of Tc has a lifetime of 6 h, just long enough to emit the gamma rays that are needed for imaging and detection by a gamma ray camera after which it is harmlessly excreted.
- The other synthetic elements from 93 to 118, after uranium (U), which complete the bottom row of the periodic table have been excluded
  - **Try to find out what these elements are? Some have only been made in the last few years.**
- The areas for all elements are approximate and for the least abundant and synthetic ones, technetium (Tc), promethium (Pr), polonium (Po), astatine (At), radon (Rn), francium (Fr), radium (Ra), actinium (Ac) and protactinium (Pa), the areas are exaggerated otherwise they would be invisible.
  - **Can you find out why there is more uranium (U) and thorium (Th) than there is of the other elements around them?**

Structure

- In this table there are no gaps between beryllium (Be) and boron (B) nor between magnesium (Mg) and aluminium (Al). The lanthanides appear in their correct place between lanthanum (La) and hafnium (Hf).

Colours

- The table is colour coded[iii] to show that in some cases we are consuming elements very fast and if we continue to do so their availability will become limited (unless we work on finding ways to recycle them).
- Of course, we do not actually run out of the element. The problem is that it gets dispersed and more difficult to use (harvesting and recycling issues).
- Helium (He) is the only element that can be lost. It is so light that when it gets into the atmosphere it escapes earth's gravity and is lost into space. So, we genuinely do lose helium
    - Helium (He) has important uses in high field magnets, which use superconductors that only work at temperatures below that of liquid nitrogen (boiling point -196 $^{o}$C) and so need liquid helium (boiling point -269 $^{o}$C) to cool them.
    - One of the main uses of these magnets is in Magnetic Resonance Imaging (MRI)
    - Another important use of helium is to dilute oxygen in the “air” that deep-sea divers breathe. Unlike nitrogen, helium does not dissolve in the blood so it does not cause any harm on decompression.
    - Special methods have been developed to recover rather than lose the helium that is breathed out by divers or used to cool magnets
    - **The use of helium for making birthday balloons should be avoided because when they go down the helium is lost forever.**

**Conflict minerals** come from mines in countries where wars are fought over the ownership of the mineral rights.

- These minerals containing tin (Sn) tantalum (Ta), tungsten (W) and gold (Au) which are highlighted in grey in *The 90 natural elements* table but can also be found in countries where there is no conflict, although their supply is limited.
- Cobalt (Co) mostly comes from mines in the conflict areas. It is often mined by children in dreadful conditions. It is not currently classified as a conflict mineral, but its status is under constant review
- A major initiative involves tracing “the life” of these elements, from mining through purification, converting them into components for the manufacture of goods, sales, resales and eventually what happens to the goods when they become waste.
- **This process is termed ‘traceability’ and it is only through this very careful kind of record keeping that we shall be able to be certain that our everyday goods have not been made from minerals where people died to provide them.**

**Expanding the life time of the elements is an essential part of the United Nation’s Sustainable Development Goals.**[iv] In a circular economy, used consumer goods are repaired, reused and recycled.

One time use and then discard cannot continue. Three examples of elements that can cause potential problems are presented below.

- Indium (In) is used in every smart screen that we use today as part of a transparent indium tin oxide conducting film.
    - Indium is also used in lasers for fibre optics, for cold welding of electrical components and in blue LEDs
    - At current usage rates, indium will be used up in 50 years and will become very expensive to collect and purify.
    - Methods to re-collect indium efficiently must therefore be developed and alternative transparent conducting coatings using earth abundant elements are in great need.
- Phosphorus (P) is an essential element of our body. It is used as a fertiliser and added to the land in the form of phosphate minerals so that there is enough for it to be taken up by plants.
    - Most of the phosphate minerals are depleting fast and as most of the phosphate ends up in run-off from fields or human urine and sewage, it is really important to develop methods for the recovery of phosphate.

- Lithium availability could cause concern because it is used in many rechargeable batteries. If all cars sold today were electric and used lithium batteries, then 800,000 tons of lithium would be required per year. Recycling, which is relatively easy for lithium, needs to be stepped up in order to keep the supply going in the future.

**Maybe you could research some of the other elements that are coloured in on the table, find out what they are used for and how they might be protected?**

**Smart phones** are used by almost everyone now.

- Take another look at the Periodic Table and you will see a phone symbol on 31[v] different elements, all of which are used in smart phones (some reports claim as many as 70).
- The supply of 17 of these elements may give cause for concern in years to come
- All the elements from conflict minerals, tin (Sn), tantalum (Ta), tungsten (W) and gold (Au), are used in smart phones so their traceability in phones is crucial.
- Did you know that ~ 10 million smart phones are changed in the European Union alone every month — imagine how many that is throughout the world; can you find out how many it is in your country?
- Many exchanged smart phones are sent to the developing world for reuse, but eventually they end up in landfill sites.
- Think how much of the scarce elements within them are being dispersed.

**Next time you are offered an upgrade of your smart phone, think again and ask yourself whether you *really* need it or whether you might keep the one you have for a year or two more and make your personal contribution to conserving these important scarce elements**

## Be a champion for sustainable development and the circular economy; protect endangered elements.

[i] http://www.periodicvideos.com/

[ii] Data from the *CRC Rubber Handbook*, as listed in https://en.wikipedia.org/wiki/Abundances_of_the_elements_(data_page) . The data for nitrogen are modified to include atmospheric nitrogen.

[iii] The data for these colours comes from a Periodic Table original put together by the *Knowledge Transfer Network* and published by *Compound Interest* at https://www.compoundchem.com/2015/08/19/endangered-elements/ It has been updated by reference to V. Zepf, B. Achzet, and A. Reller in Competition and conflicts on resource use, Eds S. Hartard and W Liebert, Springer, Cham, 2015, Chap 18, p. 239; https://link.springer.com/content/pdf/10.1007%2F978-3-319-10954-1.pdf

[iv] https://www.un.org/sustainabledevelopment/

[v] Data taken from a Periodic Table original put together by the *Knowledge Transfer Network* and published by *Compound Interest* at https://www.compoundchem.com/2014/02/19/the-chemical-elements-of-a-smartphone/ It has been updated by reference to M. Poliakoff and S. Tang, *Phil. Trans. Roy. Soc. A*, 2014, **373**, 0211; http://rsta.royalsocietypublishing.org/content/roypta/373/2037/20140211.full.pdf

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