The periodic table: A classic design

By Mark Blaskovich, The Conversation, adapted by Newsela staff on 01.02.18
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Image 1. The periodic table made out of cupcakes. Photo by: Conrad Erb/Wikimedia.

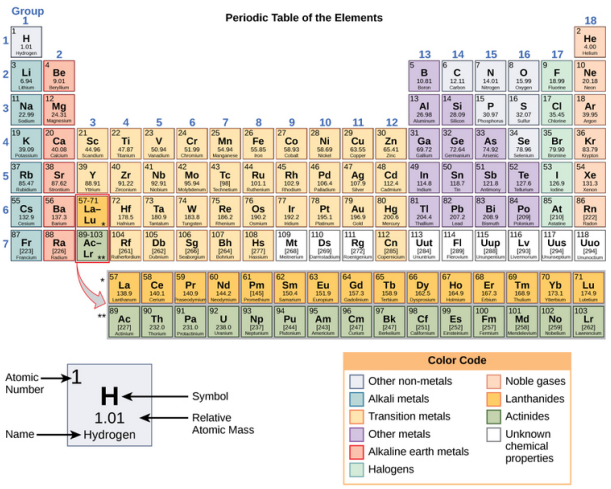
The periodic table is one of those classic images that you find in many science labs and classrooms. It's an image almost everyone has seen at some time in their life. You can also find the periodic table on T-shirts, mugs, beach towels, pillowcases and duvet covers, and plenty of other items. It even inspired a collection of short stories.

Tom Lehrer, a Harvard mathematics professor who was also a singer, wrote a song, "The Elements," that includes all the elements that were known at the time of writing in 1959. Since then, several new elements have been added to the periodic table, including the four new ones that were formally approved in 2016 by the International Union of Pure and Applied Chemistry (IUPAC).

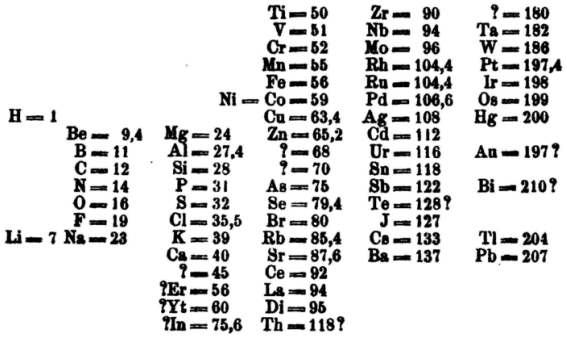
The periodic table is an attempt to organize the collection of the elements, which are all the types of atoms that make matter.

The Elements

Scientists began collecting elements in the 1700s and 1800s. As they slowly identified new ones over decades of research, they began to notice patterns and similarities in their physical properties: some were gases, some were shiny metals, some reacted violently with water, and so on.



At the time when elements were first being discovered, the structure of atoms was not known. Scientists began to look at ways to arrange them systematically so that similar properties could be grouped together, just as someone collecting seashells might try to organize them by shape or color.



Not all of the elements were known, which left gaps that made finding patterns a bit like trying to assemble a jigsaw puzzle with missing pieces. Different scientists also came up with different types of tables. The first version of the current table is generally attributed to Russian chemistry professor Dmitri Mendeleev in 1869, with an updated version in 1871. Importantly, Mendeleev left gaps in the table where he thought missing elements should be placed. Over time, these gaps were filled in and the final version as we know it today emerged.

The Atoms

To really understand the final design of the periodic table, we need to understand a bit about atoms and how they are structured. Atoms have a central core called the nucleus, made up of smaller particles called protons and neutrons. The number of protons gives an element its atomic number, found in the top left corner of each box in the periodic table.

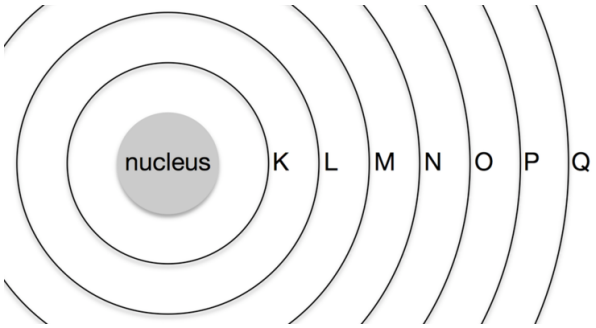
The periodic table is arranged in order of increasing atomic number (left to right, top to bottom). It ranges from element 1, which is hydrogen (H), in the top left, to the newly approved element 118, called oganesson (Og), in the bottom right. Atoms of the same element with different numbers of neutrons are called isotopes.

There is a separate box of elements below the main table (and an odd shape for the main table, with a bite taken out of the top) because of how the other parts of the atom – the electrons – are arranged.

The Electrons

We tend to think of atoms as built a bit like onions, with seven layers of electrons, called shells, surrounding the nucleus. Each row in the periodic table generally corresponds to filling up one of these shells with electrons. Each shell has subshells, and the order in which the shells and subshells get filled is based on the energy that electrons require.

In other words, the first element in each row starts a new shell containing one electron, and the last element in each row has two of the subshells in the outer shell fully occupied.



Elements in the last column, such as helium (He), neon (Ne), argon (Ar) and so on, are called the noble or inert gases. They are all gases, and they are "noble" because they rarely associate with other elements.

In contrast, the elements of the first column, with the exception of hydrogen, are called alkali metals. The first-column elements are metal-like in character and very reactive. This means that under certain conditions these elements will form bonds that connect them with other elements.

Each shell can accommodate an increasing number of electrons. The first shell only fits two, so the first row of the periodic table has only two elements: hydrogen (H) with one electron and helium (He) with two.

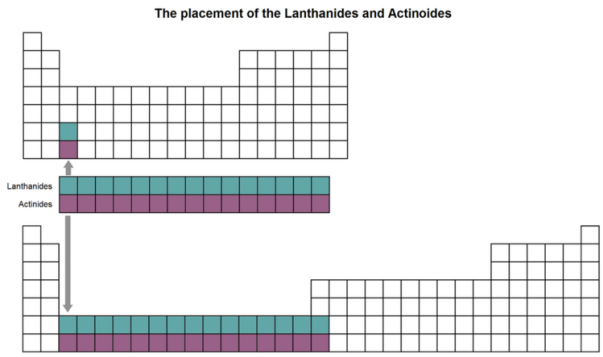
The second shell fits eight electrons, so the second row of the periodic table contains eight elements.

The third shell fits 18 electrons, but the third row still only has eight elements. This is because the extra 10 electrons don't get added to this layer until after the first two electrons are added to the fourth shell.

So the gap is expanded in the fourth row to accommodate the additional 10 elements, leading to the "bite" out of the top of the table. The extra 10 compounds in the middle section are called the transition metals.

The fourth shell holds 32 electrons, but again the extra electrons are not added to this shell until some have also been added to the fifth and sixth shells. Both the fourth and fifth rows hold 18 elements.

For the sixth and seventh rows, further expanding the table sideways to include these extra 14 elements would make it too wide to easily read. Instead, they have been inserted as a block of two rows below the main table. Elements 57 to 71 are called the lanthanides, and elements 89 to 103 are called the actinides. You can see where they would fit in if the periodic table was widened by looking at the bottom two squares in the third column of the table below.



Across The Columns

There is another complicating factor leading to the final shape of the table. As the electrons are added to each layer, they go into different subshells, which describes locations around the nucleus where they are most likely to be found. These are known by the letters s, p, d and f.

Each shell has its own layout of subshells named from 1s through 7p, which gives the total number of electrons in each shell as we progress through the periodic table.

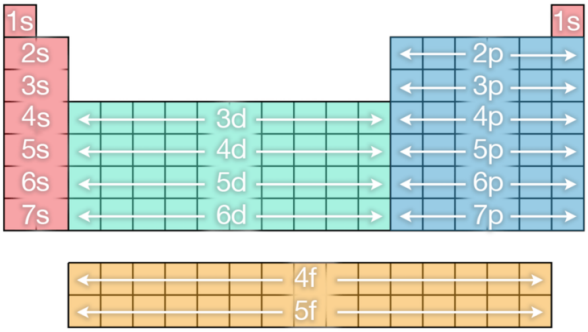
The order in which the subshells fill with electrons is not so straightforward. You can see the order in which they fill from the image below by following the order as you would read down from left to

right.

Elements within a column generally have similar properties, but in some places elements side by side can also be similar. For example, in the transition metals, the cluster of precious metals around copper (Cu), silver (Ag), gold (Au), palladium (Pd) and platinum (Pt) are quite alike.

Most of the existing elements with high atomic numbers, including the four superheavy elements added in 2016, are very unstable and have never been found in nature. Instead, they are created and studied in tiny quantities under highly artificial conditions. Theoretically, there could be further elements beyond the 118 now known (there are additional g, h and i subshells), but we don't know yet if any of these would be stable enough to be isolated.

A Classic Design



The periodic table has seen many colorful and informative versions created over the years. One of my favorites is an artistic version with original artworks for each element. Another is an interactive version with pictures of the elements, created by a team that has also published a coffee table book and an app with videos of each element.

The classic design of the periodic table can be used to play a version of the Battleship game. There are also fun versions created to help organize many different objects, including food, iPad apps and birds. As for Tom Lehrer's song "The Elements," it has yet to be updated to include all the elements known today, but it has been covered by other people over the years.

In summary, the periodic table is the chemist's chart of all elements. It is highly relevant to scientists, but it has also become embedded in popular culture.

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