editorial

Lessons from the periodic table

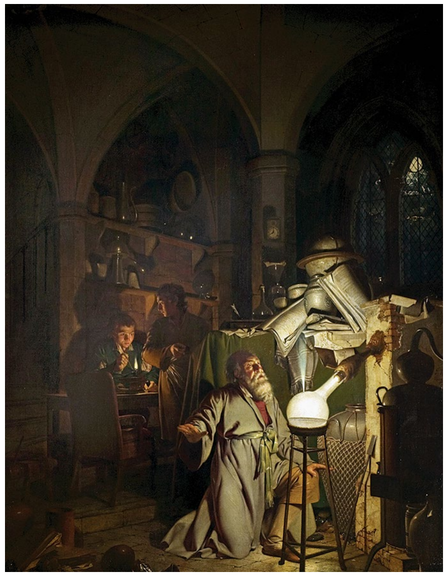
As the periodic table reaches the age of 150, we reflect on the historical search for new elements, and consider element usage trends in some key research fields.

We have come a long way from the belief that matter is composed of four elements, earth, air, fire and water. Before the rise of the scientific method, only 13 pure elements were obtained. But since the first recorded discovery of an element — phosphorus, by Hennig Brand in the 1660s (as depicted by Joseph Wright; pictured) — the observation of many elements suggested a principle could be used to arrange them. It was only in 1869, with Mendeleev's publication of an incomplete periodic table based on collation of physical properties that the table we now know was first presented, with later refinements needed to form the modern periodic table. In celebration of this 150th anniversary, the United Nations has proclaimed that 2019 is the International Year of the Periodic Table of Elements[1].

Historically, finding new elements relied on developments in characterization and processing. For example, electrolysis was first used to separate elements from their molten salts in 1785 by Martinus van Marum, thus obtaining the known elements antimony, zinc and tin. Humphry Davy then used the same approach to extract some group 1 and group 2 elements — potassium, sodium and strontium[2].

Element discovery before 1860 relied on the manipulation of chemical samples, with clues that minerals might contain new elements coming from the colour of the flame produced when burnt. At the time, however, conclusive identification required a pure element. This often required painstaking chemical reductions and oxidations of samples, followed by heating and condensation steps. With the codification of spectroscopy for elemental analysis by Robert Bunsen and Gustav Kirchhoff in 1860[3], an era arose where pure element extraction was no longer necessary. This was particularly relevant for the discovery of helium from solar spectroscopy data by Norman Lockyer in 1868[4], with samples only physically obtained 27 years later from the decay of unstable isotopes in uranium ores. Today, spectroscopies for elemental and species identification are a core part of the toolkit for modern materials scientists.

Elements with an atomic number greater than 92 tend not to occur naturally on Earth, as they quickly radioactively decay to more stable elements. To synthesize these elements, researchers collide atomic nuclei together[5] or bombard heavy nuclei with neutrons[6]. Neutrons, with their penetration depths, can be used to non-destructively map elemental distributions, allowing analysis of priceless artefacts.



The Alchemist in Search of the Philosophers Stone (1771) by Joseph Wright. Credit: Science History Images/Alamy Stock Photo

After discovery, many elements were then applied to meet practical needs, but usage was affected by many factors. For example, aluminium was originally a precious metal due to the difficulty of obtaining it in pure form. Today, much cheaper and efficient production means it can even be used for packaging.

The application of, and research on, particular elements reflects scientific, social and environmental trends. Currently, there is a focus on the greener production and storage of energy. Batteries demonstrate how this trend affects research, as performance is sensitive to chemistry. Transition and heavy metals (such as nickel, zinc and lead) were commonly used in the twentieth century due to ease of battery manufacture and low cost over alternatives such as lithium. Current trends for higher energy density (and with cheaper processing) has made lithium predominant, but other elements near lithium in the periodic table (such as sodium, magnesium, aluminium or calcium) that promise similar performance but are more abundant have also been considered[7]. Solar energy production using organic–inorganic perovskites is of research interest, but these materials contain lead, with known toxicity issues. The search for safer replacement elements typically consider elements in the same group such as tin, or adjacent such as bismuth, but performance and stability issues need to be addressed.

After 150 years, we understand much better how properties are affected by the position of elements within the periodic table. Gold (the predominant plasmonic metal), in group 10, can act as a catalyst for many reactions; and other metals in groups 10 and 11 such as silver or platinum are also of research interest as they may possess similar chemical properties. Doping to modify electronic transport in semiconductors often uses substitute elements before or after the host along the table, such as boron for silicon. In the transition metals, magnetism studies tend to focus on those elements that possess localized *d*-electrons, such as manganese-containing compounds, but the properties of materials that contain first-row transition metals, such as copper and iron, are also of research interest for high-temperature superconductivity.

There has been a synergy between our evolving understanding of the periodic table and our understanding of materials. Element position within the periodic table and sustainability considerations plays a role in determining research activity and practical applications. The space in the periodic table for new materials combinations is vast. All elements will continue to be worthy of investigation. ❐

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References

1. *UN* https://www.un.org/press/en/2017/ga11994.doc.htm (2017).
2. Davy, H. *Philos. Trans.* **98**, 1–44 (1808).
3. Kirchhoff, G. & Bunsen, R. *Ann. Phys.* **180**, 161–189 (1860).
4. Lockyer, J. N. *Proc. Roy. Soc.* **17**, 91–92 (1868).
5. Kennedy, J. W., Seaborg, G. T., Segrè, E. & Wahl, A. C. *Phys. Rev.* **70**, 555–556 (1946).
6. McMillan, E. & Abelson, P. H. *Phys. Rev.* **57**, 1185–1186 (1940).
7. Grey, C. P. & Tarascon, J. M. *Nat. Mater.* **16**, 45–56 (2017).