

Is lithium the new gold?

Jean-Marie Tarascon ponders on the value of lithium, an element known for about 200 years, whose importance is now fast increasing in view of the promises it holds for energy storage and electric cars.

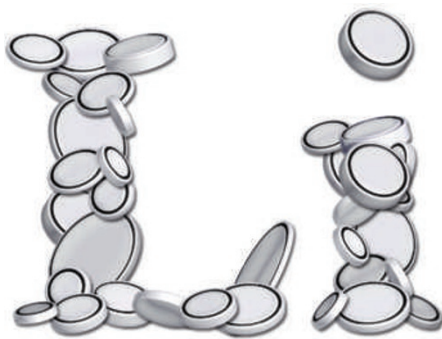
Although it has been known for almost two centuries, lithium is suddenly making the news: it is the primary ingredient of the lithium-ion batteries set to power the next generation of electric vehicles and, as such, could become as precious as gold in this century¹. It is also non-uniformly spread within the Earth's crust, sparking rumours that Andean South American countries could soon be the 'new Middle-East'. Together, these factors set the scene for controversial debates about the available reserves²⁻⁴ and the anticipated demands¹: if all cars are to become electric within 50 years, fears of a crunch in lithium resources — and thus a staggering price increase such as that faced today with fossil fuels — are permeating.

With its atomic number of 3, lithium is located in the top left corner of the periodic table. It was Johann August Arfvedson, one of Jöns Jakob Berzelius's students, who first detected its presence in 1817 while analysing the mineral petalite ($\text{LiAlSi}_4\text{O}_{10}$), itself discovered in 1800. Berzelius called this new element *lithos* (Greek word for stone).

Lithium, whose silvery-white colour tarnishes on oxidation when exposed to air, is the most electropositive metal (-3.04 V versus a standard hydrogen electrode), the lightest ($M = 6.94\text{ g mol}^{-1}$) and the least dense ($\rho = 0.53\text{ g cm}^{-3}$) solid element at room temperature, and is also highly flammable. Owing to this high reactivity, lithium is present only in compounds in nature — either in brines or hard rock minerals — and must be stored under anhydrous atmospheres, in mineral oil or sealed evacuated ampoules.

Their particular physical, chemical and electrochemical properties make lithium and its compounds attractive to many fields. Apart from the recent advent of lithium-based batteries, lithium niobate (LiNbO_3) is an important material in nonlinear optics. Engineers use lithium in high-temperature lubricants, to strengthen alloys, and for heat-transfer applications. It is also

widespread in the fine chemical industry, as organo-lithium reagents are extremely powerful bases and nucleophiles used to synthesize many chemicals. Its effect on the nervous system has also made lithium attractive as a mood-stabilizing drug, and in nuclear research tritium (^3H) is obtained by irradiating ^6Li . Annual demand has therefore grown by 7–10%, currently reaching about 160,000 tons of lithium carbonate (Li_2CO_3) per year — about 20–25% of which is for the battery sector.



Energy storage, which should help mitigate the issues of pollution, global warming and fossil-fuel shortage, is becoming more important than ever, and Li-ion batteries are now the technology of choice to develop renewable energy technology and electric vehicles. They typically consist of a Li-containing positive electrode and a Li-free negative electrode, separated by a Li-based electrolyte. From simple calculations, assuming a one-molar Li-based electrolyte and a 3.6 V LiMPO_4 electrode (where M is Fe or Mn), the demand is estimated to be about 0.8 kg Li_2CO_3 per kWh — and this number is not expected to decrease with recently developed batteries such as lithium–air or lithium–sulfur, which need an excess of lithium at the negative electrode to function properly. The fact that tritium might also be used with deuterium for nuclear fusion could increase demands.

Extracting lithium from hard rocks is laborious and expensive, however, and most of that produced (roughly 83%) at present comes

from brine lakes and salt pans: salty water is first pumped out of the lake into a series of shallow ponds, then concentrated using solar energy into a lithium chloride brine, which is subsequently treated with soda to precipitate Li_2CO_3 . Considerable amounts of lithium are present in sea water, but its recovery is trickier, and highly expensive.

It is extremely difficult to estimate the world's lithium reserves¹⁻³ — a debate typically fed by investors and venture capitalists. The present production of Li_2CO_3 is about half what would be needed to convert the 50 million cars⁴ produced every year into 'plug-in hybrid electric vehicles' (with an electric motor powered by a 7 kWh Li-ion battery and a combustion engine). The demand becomes astronomic if we consider full electric vehicles — which require an on-board battery of 40 kWh. These numbers bring fears of a potential Li shortage in a few decades, painting a dim picture.

This alarming global situation will hopefully drive researchers to investigate new battery technologies⁵ and loosen our dependence on lithium. Fortunately, the situation improves if one also considers recycling — the low melting point (180°C) of lithium metal and the very low water solubility of its fluoride, carbonate and phosphate salts make its recovery quite easy. Combining further brine exploitation with an efficient recycling process should be enough to match the demands of a 'propulsion revolution' that would solely rely on Li-ion cells, lessening geopolitical risks. □

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References

- Greene, L. *Batteries & Energy Storage Technology* 37–41 (Spring issue, 2009)
- Tahil, W. *The Trouble With Lithium* (Meridian International Research, 2006); <http://go.nature.com/jhDqLH>
- Tahil, W. *The Trouble With Lithium2* (Meridian International Research, 2008); <http://go.nature.com/AWITRo>
- <http://www.worldometers.info/cars/>
- Armand, M. & Tarascon, J. M. *Nature* **451**, 652–657 (2008).