The chemistry of magnesium turned on its head

The international scientific community agrees that the latest findings of an FAU research team will revolutionise the entire chemistry of magnesium. The research team have discovered magnesium, which usually has a double positive charge in chemical compounds, in the elemental zero-oxidation state. They have published their ground-breaking findings in the journal Nature.

In the periodic table of elements, magnesium (Mg) is a metal with low electronegativity, which means it does not easily attract electrons but easily loses both the electrons in its outer shell during chemical reactions. It therefore only exists in nature as a compound with other elements in the form of a positively charged Mg2+ cation. For example, this most stable form of Mg2+ is found in various minerals or in chlorophyll, which is the pigment that makes plants green.

Magnesium normally has double-positive charge, but now discovered in zero-oxidation state
The team at FAU led by Prof. Dr. Sjoerd Harder, Chair of Inorganic and Organometallic Chemistry, has now discovered the first complexes of magnesium in which the metal has a zero-oxidation state. The oxidation numbers in chemical compounds indicate the charge of the atoms, which means in this case that the researchers have managed to isolate elemental Mg in complex compounds.

As is so often the case in scientific research, this discovery was purely accidental. The research team had actually planned to split magnesium-magnesium bonds in order to produce magnesium radicals. Metallic sodium was used during this synthesis. The predicted result of the experiment was that the sodium would transfer one electron to the magnesium. Astonishingly, however, two sodium atoms transferred electrons to the magnesium and an Mg(0) complex that has never previously been observed was formed. The Mg centres in these complexes formally even carry a negative charge due to a unique magnesium sodium bond and thus react completely differently than conventional Mg2+ compounds. Whereas the electron-poor Mg2+ cations can accept electrons, the electron-rich Mg(0) reacts like a negatively charged anion by losing electrons.

This complex is soluble in organic solvents like toluene or benzene and is an extremely strong reducing agent, which is an element or compound that donates electrons to another element or compound. Slightly heating the complex led the Mg(0) to donate some of its electrons to the positively charged sodium cation (Na+), which then became elemental sodium metal Na(0). This is quite unusual, since sodium itself is a metal that has an even stronger tendency to lose electrons. This reaction created a new complex: three atoms of magnesium strung together like beads on a necklace. This triple core magnesium cluster reacts like atomic Mg(0) and can be considered as the smallest form of magnesium metal, one that is soluble in organic solvents. This new class of magnesium complexes represents a landmark in the chemistry of magnesium. The FAU research team led by Prof. Harder expect to discover further unusual reactivity of this soluble and extremely strong reducing agent.
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Originalpublikation:
https://www.nature.com/articles/s41586-021-03401-w