in your element

The allure of aluminium

Daniel Rabinovich outlines the history, properties and uses of aluminium — one of the most versatile, pervasive and inexpensive metals today, yet it was considered a rare and costly element only 150 years ago.

It is hard to believe that aluminium was once more expensive than gold and that, in the mid-nineteenth century, Napoleon III used silverware made of the light metal when he really wanted to impress his guests at stately dinners. Even though element 13 is the most abundant metal in the Earth's crust (~8%) and is present in more than 270 different minerals, its high affinity for oxygen and the chemical stability of its oxides and silicates precluded its isolation in pure form for a long time. The first pure sample of aluminium was obtained in 1827 by the German chemist Friedrich Wöhler, who also began studying its fascinating physical and chemical attributes.

The French chemist Henri Sainte-Claire Deville (1818–1881) developed a method of preparing larger quantities of aluminium in 1854, and soon published the first comprehensive book describing its manufacture, properties and emerging applications[1].

The attractive properties of the newfangled metal quickly became clear, including low density, high tensile strength and malleability, good thermal and electrical conductivity, and a remarkable resistance to corrosion. Jules Verne eloquently wrote in *From the Earth to the Moon* (1865) that "This valuable metal possesses the whiteness of silver, the indestructibility of gold, the tenacity of iron, the fusibility of copper, the lightness of glass. It is easily wrought, it is very widely distributed, forming the basis of most of the rocks, is three times lighter than iron, and seems to have been created with the express purpose of furnishing us with the material for our projectile." The price of aluminium, however, was still comparable to that of silver, which hampered the development of large-scale applications and motivated the search for an alternative and more economical preparation process.

It was only in 1886 that Charles M. Hall in the US and Paul L. T. Héroult in France, almost simultaneously and completely independently, devised aluminium production processes that relied on the electrolysis of alumina (Al_2O_3) dissolved in molten cryolite (Na_3AlF_6). An efficient process for the extraction and purification of alumina from bauxite, the most important aluminium ore, was developed within a couple of years by the Austrian chemist Karl Josef Bayer, son of the founder of the famous German chemical and pharmaceutical company, and the 'Hall–Héroult' process became economically viable. By the early 1960s element 13 became the most widely used non-ferrous metal in the world, even more so than copper.

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Applications of aluminium and its alloys range from construction and the transportation industry to the manufacture of electric power lines, packaging materials, cooking utensils and a myriad of other household goods. Another important feature of this ubiquitous metal, one that has significant economic and environmental consequences, is the ease with which it can be recycled. The recovery of secondary aluminium requires only about 5% of the energy necessary to produce new metal from bauxite, while also leading to a decreased use of landfill space and a reduced emission of greenhouse gases.

In contrast to the relatively short history of the pure metal, compounds of aluminium have long been known: alum, a hydrated sulfate of potassium and aluminium, $KAl(SO_4)_2 \cdot 12H_2O$, was used as an astringent and a dyeing mordant in ancient Greece and Rome. Aluminium chloride, $AlCl_3$, a common Lewis acid, is extensively applied in Friedel–Crafts acylation and alkylation reactions, and aluminium chlorohydrate, $Al_2Cl(OH)_5$, is the active ingredient in many antiperspirants. Large quantities of methylaluminoxane, a generic name used to describe the ill-defined mixture of species obtained by partial hydrolysis of trimethylaluminium, are employed in the Ziegler–Natta polymerization of olefins.

The availability of an ever-increasing variety of aluminium coordination complexes has also prompted many recent developments in the chemistry of this metal, often with potential applications to catalysis and organic synthesis[2]. Other active areas of research range from the preparation of unusual aluminium(I) compounds, including organometallic species[3] and metalloid clusters[4], to the synthesis of Schiff base derivatives that effectively break down organophosphate nerve agents and pesticides[5].

The element once dubbed the magic metal by *National Geographic* continues to be a source of inspiration for scientists, engineers and even artists and designers[6]. Let us remember its rich chemistry, fascinating history and multifarious applications the next time we wrap a sandwich in aluminium foil or drink a carbonated beverage from a can! ❐

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