

# Mesmerized by mercury

Joel D. Blum considers the two faces of mercury. It has many unique and useful properties in chemistry — yet it comes with a dark and dangerous side.

Mercury was central to the study of alchemy, the philosophical tradition that laid many of the foundations for both the principles and procedures of modern chemistry. European alchemists believed that mercury was a main ingredient in all metals and could be transmuted into gold by combination with other metals. Although we now know that this is not the case, mercury does dissolve fine flakes of gold and is widely used for this purpose in artisanal gold mining.

Its chemical symbol, Hg, comes from its former name hydrargyrum, which translates from Latin as ‘water silver’ and refers to its shiny liquid metallic form. This is also the origin of the nickname quicksilver — mercury is the only liquid metal at room temperature, a phenomenon recently shown to be due to the effects of relativity<sup>1</sup>.

A dense liquid metal is a very useful material and mercury has widespread applications, from thermometers and barometers to electrical switches, batteries, dental amalgams, light bulbs and even for floating the mirrors of high-powered telescopes. It has also been widely used in electrolytic cells in chemical manufacturing.

Mercury may sound like a ‘wonder element’, but it also has a darker side. In the 1950s, much of the world supply of mercury was used to separate the <sup>6</sup>Li isotope by amalgamation for use in making hydrogen bombs. And in virtually all of its forms, element 80 is a highly potent neurotoxin. Exposure to mercuric nitrate by hat-makers during the treatment of fur, and the resulting symptoms of poisoning, led to the expression ‘mad as a hatter’; similarly, a neurological disorder caused by exposure to methylmercury — a highly toxic and bio-accumulative compound — from consumption of fish contaminated by nearby industry in a Japanese coastal town became known as Minamata disease.



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Mercury occurs naturally in coal deposits; on combustion, gaseous elemental mercury is released. Because it can have an atmospheric lifetime of over a year, it is distributed to every corner of the globe. Some gaseous mercury reacts with tree foliage and is deposited directly into forests. Photochemical reactions in the atmosphere also oxidize elemental mercury and the oxidized form is then deposited in precipitation, reaching even the most remote lakes, oceans and terrestrial ecosystems<sup>2</sup>. Meanwhile, the widespread use of mercury in household products has also resulted in its presence in the waste stream.

The inorganic forms of mercury are generally deposited from the atmosphere in low enough concentrations that they do not represent a health concern. However, a number of anaerobic microbes have the ability to transform inorganic mercury into methylmercury. Earlier this year the genes responsible for mercury methylation were identified, and it has now become possible to screen microbes for their ability to methylate mercury<sup>3</sup>. Methylmercury biomagnifies up aquatic and terrestrial food chains, reaching levels high enough to be toxic for animals feeding at high trophic levels — including predatory fish, fish-eating mammals and insect-eating birds.

Microbial and photochemical reactions in the environment convert some methylmercury back to its inorganic forms,

so the competition between methylation and demethylation reactions ultimately controls levels in the environment<sup>2</sup>. To better understand the behaviour of mercury in the environment, and the transformations that control its mobility and toxicity, researchers seek means of fingerprinting its various sources. In 2007, my research group identified a phenomenon whereby magnetic isotopes of mercury react during photochemical reactions at different rates from even-mass isotopes, leading to mass-independent isotope fractionation (MIF)<sup>4</sup>.

The chemistry behind the MIF phenomenon is interesting in its own right. It can occur during reactions involving short-lived radical pairs (by the magnetic isotope effect) and also in equilibrium reactions (by the nuclear volume effect)<sup>4,5</sup>. The ratio of mass-independent to mass-dependent isotope fractionation, and the ratio of MIF between the two odd-mass isotopes <sup>199</sup>Hg and <sup>201</sup>Hg, can be used to determine reaction mechanisms and the ligands associated with mercury. Thus isotopes are proving to be a very useful tool in teasing apart the complex biogeochemistry of this element<sup>5</sup>.

Many years ago when I began research on mercury, a wise senior colleague warned me that “once you delve into the chemical behaviour of mercury — there is no turning back.” I dismissed this comment as not pertaining to me, but I have since learned that the rich chemistry of mercury, just like the shimmer of the liquid metal, catches one’s attention and will not let it go. □

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