Learn About ...

MERCURY

Mercury is named after the fleet-footed Roman god Mercury. Its chemical symbol, Hg, derives from its Latin name, hydrargyrum, which means liquid silver. Mercury, the only metal that is a liquid at room temperature, melts at –38.9 ºC, and boils at 356.6 ºC.

View photos of a liquid mercury fountain

Elemental mercury is extremely toxic and rarely occurs free in nature. It is often found as the mineral cinnabar, HgS, which is a red solid at room temperature. Mercury is produced from cinnabar by heating it in air. The mercury vapor that is produced is distilled and cooled to form liquid mercury.

$$HgS\,(s) + O_2\,(g) \longrightarrow Hg\,(g) + SO_2\,(g)$$

Mercury is used in thermometers, barometers, electrical switches, mercury vapor lamps, fluorescent lamps, paints, fungicides, insecticides, and antiseptics. Mercury vapor lamps are often used to light streets and gymnasiums.

More information on how mercury is used in lamps

Mercury readily forms alloys known as amalgams with other metals and has been used for the extraction of precious metals such as gold. Dental amalgams are prepared by mixing approximately equal parts liquid mercury and an alloy powder composed of silver, tin, and copper. Industrially, mercury has been used primarily in battery manufacturing and chlorine-alkali production. In the chloralkali industry, the major process is electrolysis of aqueous sodium chloride, NaCl, to produce sodium hydroxide, NaOH, and chlorine, Cl_2. The aqueous chloride ion is oxidized at a carbon anode in the reaction, and water is reduced at a liquid mercury cathode.

anode: $2Cl^-(aq) \longrightarrow Cl_2(g) + 2e^-$

cathode: $2e^- + 2Na^+(aq) + 2H_2O \longrightarrow 2Na^+(aq) + 2OH^-(aq) + H_2(g)$

Mercury electrolytic cells are not the only types of cells that can be used for this process, but they were widely used for economic reasons. Mercury was commonly used in thermometers and barometers because it has a high rate of thermal expansion that is fairly constant over a wide temperature range. For safety reasons, mercury is no longer used in thermometers, and as a result of state and federal legislation and voluntary programs, most uses in paints and batteries have been limited.

In the early days of the Industrial Revolution, mercury nitrate, $Hg(NO_3)_2$, was used to soften rabbit fur to make felt hats. Mercury nitrate is a form of inorganic mercury that isn't absorbed by the body as easily as other species, but it was toxic enough to affect the brains of many hatmakers. The phrase "mad as a hatter", and the Mad Hatter of Lewis Carroll's novel *Alice in Wonderland*, are both from the same source, which is the toxic effect of mercury on the central nervous system. Symptoms of chronic mercury exposure include increased excitability, mental instability, tendency to weep, fine tremors of the hands and feet, and personality changes. In milder cases of mercury poisoning, reduced motor skills and dulled senses of touch, taste, and sight are reversible if exposure to mercury is halted. Unborn children are at greatest risk from low-level exposure to mercury. The most infamous case of severe mercury poisoning occurred at Minamata Bay, Japan, in 1952. The Chisson Chemical Company dumped mercury in Minamata harbor, and the residents of local fishing villages ate mercury-contaminated fish from the harbor. Hundreds of people were affected, and 68 people died.

In the late 1980s, researchers found that fish taken from lakes in very remote areas from all around the world had high levels of mercury. These findings implicated atmospheric deposition as a major contaminant source of mercury. Mercury is found in the environment as a result of natural and human activities. Natural sources include volcanoes, natural mercury deposits, and volatilization from the ocean. The primary human-related sources include coal combustion, chlorine alkali processing, waste incineration, and metal processing. Best estimates to date suggest that human activities have about doubled or tripled the amount of mercury in the atmosphere, and the atmospheric burden is increasing by about 1.5 percent per year. Global anthropogenic emissions of mercury are estimated to range between 2000 and 6000 metric tons per year. Electric utilities, municipal waste combustors, commercial and industrial boilers, and medical waste incinerators account for approximately 80 percent of the total amount. Coal-fired utility boilers are the largest point source of unregulated mercury emissions in the United States.

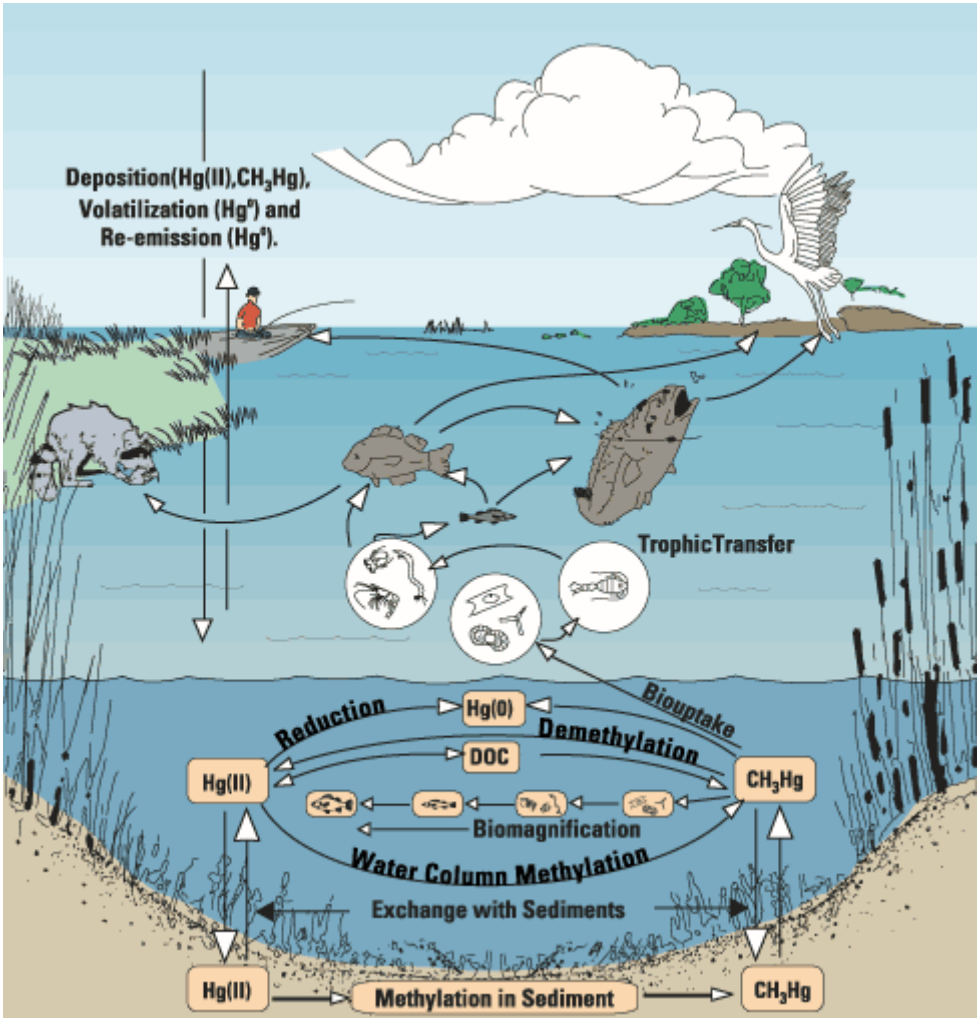
Mercury exists in three oxidation states: Hg^o (elemental mercury), Hg_2^{2+} (mercurous mercury), and Hg^{2+}(mercuric mercury). The properties and chemical behavior of mercury strongly depend on its oxidation state and its chemical form. Mercurous and mercuric mercury form numerous inorganic and organic chemical compounds. Organic forms of mercury, especially methylmercury, $CH_3Hg(II)X$, where "X" is a ligand, typically Cl^- or OH^-, are the most toxic forms. Airborne mercury is primarily inorganic mercury. Elemental mercury can remain airborne for over a year and be transported thousands of miles before it is oxidized to $Hg^{2+}$and deposited. The fraction of Hg^{2+} that occurs in mercury emitted from sources such as coal-fired power plants is not well established; however, if it turns out that a lot of the presumed Hg^{2+} is in fact elemental mercury, then mercury deposition is not a local and regional issue, but part of a larger global problem.

Airborne mercury is eventually deposited to the ground and may ultimately make its way into lakes, rivers, streams, and wetlands, where some of it is transformed into methylmercury. Like many environmental contaminants, mercury bioaccumulates in fish, aquatic invertebrates, and mammals. Bioaccumulation is the process by which organisms can take up contaminants more rapidly than their bodies can eliminate them. The concentration of mercury in an organism tends to increase with increasing trophic level or position in the food chain. This occurs because the food source for organisms higher on the food chain is progressively more concentrated in mercury, thus magnifying bioaccumulation rates at the top of the food chain. The longer an organism lives, the more time they have to bioaccumulate mercury; therefore, larger predatory game fish tend to have the highest levels of mercury. More than 95% of the mercury found in fish and shellfish is in the form of methylmercury. Unlike organic contaminants, such as PCBs and dioxins, which concentrate in fish skin and fat, mercury concentrates in the muscle tissue of fish and can't be filleted or cooked out of consumable fish.

In the environment, sulfate-reducing bacteria take up mercury in its inorganic form and through metabolic processes convert it to methylmercury. Sulfate-reducing bacteria are found in anaerobic conditions, typical of the well-buried muddy sediments of rivers, lakes, and oceans where methylmercury concentrations tend to be highest. Sulfate-reducing bacteria use sulfur rather than oxygen as their cellular energy-driving system. One hypothesis is that the uptake of inorganic mercury by sulfate-reducing bacteria occurs via passive diffusion of the dissolved complex HgS. Once the bacterium has taken up this complex, it utilizes detoxification enzymes to strip the sulfur group from the complex and replaces it with a methyl group:

$$HgS \xrightarrow{\text{bacteria}} CH_3Hg(II)X + H_2S$$

Upon methylation, the sulfate-reducing bacteria transport the new mercury complex back to the aquatic environment, where it is taken up by other microorganisms.



Aquatic Mercury Cycle from The US Geological Survey

The major source of methylmercury exposure in humans is consumption of fish, marine mammals, and crustaceans. Once inside the human body, roughly 95% of the fish-derived methylmercury is absorbed from the gastrointestinal tract and distributed throughout the body. Uptake and accumulation of methylmercury is rapid due to the formation of methylmercury-cysteine complexes. Methylmercury is believed to cause toxicity by binding the sulfhydryl groups at the active centers of critical enzymes and structural proteins. Binding of methylmercury to these moieties constitutively alters the structure of the protein, inactivating or significantly lowering its functional capabilities.

Over forty states in the U.S. have issued health advisories regulating fish consumption due to high mercury levels. There are more than 15,000 lakes in Wisconsin, and all of them are covered by an advisory warning people about the level of mercury in the fish caught in those lakes. The Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA) have jointly issued a consumer advisory about mercury in fish and shellfish. They recommend that women who may become pregnant, pregnant women, nursing mothers, and young children not eat shark, swordfish, king mackerel, or tilefish because they contain high levels of mercury, and that they limit fish and shellfish consumption to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury. Five of the most commonly eaten fish that are low in mercury are shrimp, canned light tuna, salmon, pollock, and catfish.

For more on mercury and other elements visit
Chemical and Engineering News Magazine's Periodic Table

Further Reading:

Resuscitating the Mercury Beating Heart: An Improvement on the Classic Demo

Daniel Stribling, Christopher R. Brewer, and Kenneth A. Goldsby
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