KPU International Journal of Engineering & Technology
Volume 5, Issue 1, Mar. 2025
e-ISSN:2790-0819, p-ISSN:2790-0800

Date Received: 2025-02-16
Date Accepted: 2025-03-29
Date Published: 2025-03-30

Investigating the Properties, Applications, and Health Risks of Mercury

LILA MIA QADIRI*

Department of Chemistry Natural Science faculty of Kabul Educational University, Kabul, Afghanistan.
Email: lailamiaqadiri1@gmail.com.

Abstract

The article outlines mercury's dual existence in nature as both a pure element and as cinnabar (HgS). Notable for its liquid state at standard temperature and pressure, mercury is highly volatile and can be hazardous to health. The article emphasizes the formation of mercury amalgams with other metals and the toxic properties of mercury salts like mercury (I) chloride (calomel). The paper also covers mercury's diverse industrial, medical, and everyday uses, alongside the severe health consequences of exposure, including neurological and respiratory damage. The health risks underscore the importance of timely intervention upon exposure. The study methodology is based on library and internet research, and the article serves as an educational resource.

Keywords: Amalgam, Calomel, Hg (Hydrargyrum) or Mercury.

* Corresponding Author

1. Introduction

Mercury, a naturally occurring element, exists as both a pure metal and a compound, primarily as cinnabar (HgS). Known as "liquid silver" for its shiny, silvery appearance, mercury remains the only metal liquid at standard temperature and pressure. It is volatile at room temperature, and its vapors can be hazardous. Unlike most liquids, mercury forms a convex meniscus and droplets that tend to form spherical shapes. A notable salt of mercury is mercury (I) chloride (calomel), which is toxic.

Mercury (Hg), a transition metal, has been historically known as "quicksilver" due to its liquid state at room temperature and its silvery appearance. The name "mercury" is derived from the Latin *Hydrargyrum*, which translates to "liquid silver." The metal is primarily obtained from cinnabar (HgS), its most important mineral. When cinnabar is heated, mercury is released as a vapor, which is then condensed into its liquid form.[5]

Mercury has an atomic number of 80 and a density of 13.6 g/cm³, making it one of the densest liquids at room temperature. Unlike most substances, mercury remains in liquid form under standard temperature and pressure (STP), a unique characteristic among metals.

Mercury is a heavy metal with excellent electrical conductivity. Its behavior is also notable in narrow, convex tubes, where it forms a smooth liquid column that does not adhere to the surface, reminiscent of the way water beads up on a duck's feathers. This non-wettability and its fluidity are some of the defining traits of mercury. [3]

Mercury plays a significant role across various industries, medicine, and daily life due to its unique properties. For instance, mercury readily dissolves with most metals, except iron, to form a mixture called an amalgam. This amalgam has long been used in the medical field, particularly for dental fillings, due to its ability to bond well with tooth structures.

Another noteworthy compound of mercury is mercury chloride, also known as calomel (Hg_2Cl_2). This substance has toxic properties, making it dangerous to handle, but it also possesses antiseptic qualities. Historically, it was utilized in skin care treatments and to promote the fertility of animals, although its use has become highly restricted due to its toxicity.

In industry, mercury has a wide range of applications. It is involved in the production of industrial chemicals, electrical and electronic components, and precision instruments like thermometers and pressure gauges. Additionally, mercury is used in the creation of diffusion pumps, steam lamps, advertising signs, and mercury switches. In some cases, it plays a role in electrolysis processes and is used as a catalyst.

Given mercury's versatility, its handling requires caution due to its hazardous nature, but it remains an essential material in various technological and medical fields.

To summarize, Mercury (Hg) is a unique and versatile metal that has been of great historical and industrial significance. Its liquid state at room temperature, silvery appearance, and remarkable properties make it stand out among other metals. Historically known as "quicksilver," mercury is derived from cinnabar (HgS), which, when heated, releases mercury vapor that can then be condensed into liquid form.

With an atomic number of 80 and a density of 13.6 g/cm³, mercury is one of the densest liquids at room temperature. Unlike most metals, it remains liquid under standard

temperature and pressure (STP), which is a distinctive feature. Mercury's excellent electrical conductivity and behavior in confined spaces, such as narrow, convex tubes, make it particularly interesting. In these tubes, mercury forms a smooth, non-wetting liquid column, similar to the way water beads up on a duck's feathers, demonstrating its fluidity and non-wettability. Mercury has a wide range of applications across industries, medicine, and daily life due to its unique properties. [3],[4] It dissolves with most metals, excluding iron, to form amalgams. These amalgams have been historically important in the medical field, particularly for dental fillings, because they bond well with tooth structures. Mercury's compound mercury chloride (calomel), while toxic, has antiseptic properties and was used in skin care treatments and fertility promotion, though its use is now highly restricted.

In industry, mercury plays a crucial role in the production of industrial chemicals, electronic components, precision instruments like thermometers and pressure gauges, and processes like electrolysis. It is also used in diffusion pumps, steam lamps, advertising signs, and mercury switches.

Despite its utility, mercury is hazardous, and its handling requires caution. Its toxic properties necessitate careful management, but it remains indispensable in various technological, medical, and industrial applications.

2. Research Problem: Examination of the Properties, Uses, and Harms of Mercury

Mercury is a naturally occurring heavy metal known for its distinctive physical and chemical properties, which have made it valuable in industries like manufacturing, medicine, and daily life. However, despite its usefulness, mercury is highly toxic and presents significant environmental and health risks. This research aims to examine mercury’s dual nature, exploring both its essential applications and the potential dangers it poses. The focus will be on understanding its properties, investigating its uses, assessing the harm it causes, and exploring strategies to reduce its toxic effects.

2.1 Properties of Mercury

Mercury symbolized as Hg on the periodic table, is unique for being the only metal that remains liquid at room temperature. It has a high density and excellent conductivity, making it valuable for a variety of industrial and scientific applications. It can vaporize easily at room temperature, which is one of the reasons it is so dangerous to human health when inhaled in its vaporized form.

2.2 Uses of Mercury

Mercury has a variety of uses across different fields:

1. **Industry**: It is used in the production of chlorine and caustic soda in chemical industries. Additionally, mercury is used in the production of electrical switches, thermostats, and fluorescent lighting.
2. **Medicine**: Historically, mercury compounds were used in medicines, such as in the treatment of syphilis. While modern medicine has largely moved away from

such uses, mercury is still used in some vaccines and as an antiseptic in small quantities.

3. **Daily Life**: Mercury can be found in thermometers, barometers, and even some batteries.

2.3 Harms of Mercury

Despite its beneficial uses, mercury is known for its highly toxic effects, particularly on the nervous system. There are several forms of mercury, including elemental mercury (liquid form), inorganic mercury compounds, and organic mercury compounds (e.g., methylmercury). Each form of mercury can pose distinct health risks:

- **Elemental Mercury**: Inhalation of mercury vapors can lead to neurological and kidney damage. It is especially dangerous when spilled in environments that are poorly ventilated.
- **Inorganic Mercury Compounds**: These can cause damage to the gastrointestinal tract, kidneys, and nervous system if ingested or inhaled.
- **Methylmercury**: This organic form, often found in contaminated fish and seafood, is particularly harmful to pregnant women, fetuses, and young children, leading to developmental and neurological damage.

2.4 Preventing Mercury Poisoning

Given its harmful effects, it is critical to mitigate mercury exposure. Some preventive measures include:

1. **Regulation and Restrictions**: International agreements like the Minamata Convention on Mercury have been established to limit the use of mercury and reduce environmental contamination. Such regulations encourage the development of safer alternatives to mercury in industrial and medical applications.
2. **Safe Disposal**: Proper disposal of mercury-containing products can help minimize the risk of environmental contamination.
3. **Public Education**: Raising awareness about the potential risks of mercury exposure, especially in relation to its presence in fish and everyday products, is essential.
4. **Safer Alternatives**: Investment in research to develop mercury-free technologies can provide long-term solutions for reducing reliance on this toxic metal.

3. Need for Further Research

The harmful effects of mercury, combined with its widespread use, underscore the importance of continued research. Understanding the various ways mercury can be safely handled and replaced with less harmful substances is crucial for reducing its impact on public health and the environment. Moreover, more comprehensive data on how mercury affects different population groups and ecosystems will help inform better regulatory practices and more effective preventive measures.

4. Research Questions

1. What are the properties and characteristics of mercury?
2. In which industries or applications is mercury used?
3. What are the potential harms of mercury in daily life?

5. Research Goal

1. To identify the physical, chemical, and toxicological properties of mercury.
2. To explore the various uses of mercury in different fields (e.g., industry, medicine, science, etc.).
3. To analyze the potential harms and health risks associated with mercury exposure in daily life.

6. Research Methodology

This research was conducted with the aim of investigating mercury's properties, applications, and potential hazards. The methodology includes a combination of Internet-based research that was practically completed based on library books.

- **Data Collection:** Information was gathered through a review of academic research papers, scientific books, reliable internet resources, and governmental or non-governmental reports on the subject currently available in the University libraries.
- **Approach:** A descriptive research design was employed to summarize the properties and uses of mercury, alongside its harmful effects using various Mercury academic books. Additionally, a library research method was used, relying on secondary data and existing literature. This includes studies on the chemistry of mercury, its history of use, and documented health impacts.
- **Research limitation:** As a woman, it can be challenging to visit multiple labs and libraries to access resources and gain hands-on experience in applying knowledge. The process of gathering various books and printed materials from the internet for the purpose of completing this research was both time-consuming and difficult.

This section of the research text provides a detailed overview of mercury, its properties, chemical behavior, and historical applications, particularly in medicine and industrial uses.

1. **Mercury's Electron Structure and Name Origin**:
    - Mercury (Hg) has a complex electron structure ($1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $4s^2$, $3d^{10}$,$4p^6$, $5s^2$,$4d^{10}$, 5p6, $4f^{14}$, $5d^{10}$, $6s^2$) were considered for this element as outlined by Nahalgar (2006).
    - The name "Mercury" comes from the Latinized Greek word "Hydrargyrous," meaning "juicy silver," reflecting its liquid state and silvery appearance.
2. **Properties of Mercury**:
    - Mercury is one of the few metals that is liquid at room temperature, has a low melting point, and is toxic due to its ability to vaporize at ambient temperatures, making inhalation hazardous. (Hossaini, 2016)

- Mercury has distinctive properties, such as forming a convex surface when placed in a container and existing in both pure and compound forms.
- Unlike most liquids, mercury forms small droplets that resemble pellets.
- It can form various compounds such as mercuric oxide (HgO), which is important historically for the discovery of oxygen.
  $2Hg+O_2 \rightarrow 2HgO$
  $2HgO \rightarrow 2Hg+O_2$

3. **Mercury's Interaction with Other Metals**:
   - Mercury can dissolve most metals (except for platinum, tungsten, and tantalum) and form amalgams, which are important in industrial applications, including gold extraction.
   - Amalgams are alloys of mercury with metals like silver, copper, indium, tin, and zinc.
4. **Mercury Salts and Their Uses**:
   - Mercury chloride ($HgCl_2$), also known as calomel, is a significant mercury salt. Historically, it was used as a medicine and for various treatments, despite its toxicity. (Samargol, 2011)
   - Calomel was used for a wide range of ailments in ancient times, including syphilis and tuberculosis. However, it has a toxic effect, particularly on the kidneys, and its use is now limited due to its harmful properties.
5. **Mercury in Medicine and Photography**:
   - Historically, mercury compounds, especially mercury chloride, were used in medical treatments and as photographic enhancers.
   - The toxic nature of mercury chloride, especially its corrosive properties, can cause internal damage like ulcers and kidney failure, though it doesn't cross the blood-brain barrier easily.
   - Mercury's historical use in medicine, particularly for syphilis, has now been replaced by more effective and safer treatments.
6. **Toxicity and Handling**:
   - Due to its toxicity, mercury compounds like $HgCl_2$ can cause severe damage to the gastrointestinal system, kidneys, and other organs if ingested or absorbed.
   - Special care should be taken when handling mercury and its compounds to avoid inhaling its vapors or contact with the skin.

In essence, mercury is a fascinating element with a variety of industrial, medicinal, and historical uses, but its toxicity requires careful handling and consideration in modern applications.

(www.pub.chem.ncbi.nllm.nih.goo.org), (www.wikipedia.nin.org)

$Hg_2(NO_3)_2+4HCl=2HgCl_2+2H_2O+2NO_2$

6.1 Properties

Mercury (Hg) is a unique element with distinct chemical properties, particularly in its interactions with acids. While it does not react significantly with many acids, it shows reactivity with strong oxidizing acids such as concentrated sulfuric acid and nitric acid.

In these reactions, mercury forms compounds such as sulfides, nitrides, and chlorides, depending on the specific acid involved. Mercury can even interact with small sulfur particles, which are utilized in devices such as mercury settling kits designed to absorb mercury vapors. [4]

Mercury exists primarily in the mercuric state (Hg^{+2}), though there are also compounds where mercury exists in other forms, such as the mercury ion (Hg_2^{2+}). In these compounds, the bonding is described by the use of both electrons from the sulfur 6-level in the connectivity between ions. In mercurial (Hg^{+2}) and mercuric (Hg_2^{+2}) compounds, the mercury ion typically takes the form of Hg_2^{2+} rather than Hg^{+}. When mercury compounds are formed with monoatomic ions, the resulting solutions exhibit electrical conductivity that corresponds to the presence of one ion with two charges and two ions with one charge, as opposed to a simple cation and anion each with one charge. This unique behavior is a key characteristic of mercury's chemistry, especially in the context of its compounds and their behavior in solutions.

1. **Crystallographic and Spectral Evidence**: Studies confirm the presence of Hg-Hg units in mercury compounds, with Raman spectra showing a distinct peak indicative of a mercury-mercury covalent bond.
2. **Solubility and Precipitation**: While some mercury salts (e.g., nitride and chloride) dissolve in water, most mercury compounds are insoluble. Adding chlorine or sulfide ions to a mercury nitride solution forms a white precipitate, such as Hg_2Cl_2 or Hg_2SO_4, which is a mix of mercuric oxide and mercury.
   $Hg_2^{+2} + 2OH^- \rightarrow Hg + HgO + H_2O$
3. **Disproportionation**: In solution, mercury ions can undergo disproportionation, leading to the formation of both mercuric sulfide and elemental mercury. This phenomenon is akin to the behavior of hydrogen sulfide.
4. **Mercury Complex Formation**: Mercury ions can form complexes with sulfide and oxalate ions, although stable mercury complexes are not easily formed. This often results in the creation of free mercuric complexes instead.
5. **Coordination and Structure**: Mercury (II) can adopt tetrahedral, linear, or octahedral geometries depending on the situation. Its lower coordination number compared to zinc and cadmium is attributed to its lower acid strength.
6. **Mercury Compounds**: Despite having a lower acid strength, mercury (II) forms ionic compounds with strongly electronegative ions (e.g., sulfide, nitride, fluoride). To prevent hydrolysis in aqueous solutions, the environment must be acidic. HgF_2, a weak acid, and salt, decomposes into mercuric oxide and hydrofluoric acid.

1. **Mercuric Oxide Formation**
   - When an acidified solution of a mercuric salt reacts with alkali, mercuric oxide (HgO) forms a yellow precipitate.
   - Heating this yellow mercuric oxide causes a change in the particle size, and it transforms into the red form of mercuric oxide.

2. **Solubility and Mercury (II) Hydroxide**
    - Mercuric oxide is slightly soluble in water. When it dissolves, it forms mercuric hydroxide ($Hg(OH)_2$).
3. **Mercuric Chloride**:
    - Mercuric chloride ($HgCl_2$) is covalent in nature (unlike its fluoride counterpart) and is less dissociated in aqueous solution. The formula of the solid is Cl-Hg-Cl.
4. **Complex Formation**:
    - Cyanide and halide ions (except fluoride) can form complexes with mercury. For example, mercuric ions react with iodide ions (I^-) to form the complex $[HgI_4]^{2-}$.
      $HgI + 2I^- \rightarrow [HgI_4]^{2-}$
5. **Reaction with Ammonia**:
    - The interaction of mercuric chloride with ammonia can yield several products, depending on the conditions:
        - $Hg_2NCl \cdot H_2O$
        - $HgNH_2Cl$
        - $[Hg(NH_3)_2]Cl_2$
    - The presence of ammonia causes the formation of these products, which can vary in concentration based on the conditions of the reaction.
6. **Mercury Ammonia Complexes**:
    - In the absence of complexing anions like chloride, mercury (II) can form the tetraamine $[Hg(NH_3)_4]^{2+}$ ion when ammonia is added.
7. **Organic Mercury Compounds**:
    - Mercury also forms several organic compounds, such as alkyl and aryl mercury compounds (R_2Hg and RHgX). These compounds are highly toxic and exhibit limited interaction with other substances (Giola1376).

6.2 Lower Oxidation States

According to Cooks (1401), mercury (Hg) complexes, specifically those involving Hg^{2+}, are coordinated to ligands, similar to complexes formed with zinc (Zn) and cadmium (Cd). However, these complexes are significantly less stable for Zn and Cd. Group 12 elements—Zn, Cd, and Hg—have electron configurations $ns^2(n-1)d^{10}ns^2$, where n = 4/5 and 6 for Zn, Cd, and Hg. respectively. These elements belong to the d-block, but their (n-1) d orbitals are not as reactive or fully utilized in chemical bonding. Consequently, these elements exhibit characteristics similar to transition metals, though their behavior differs from the highly electropositive Group 2 elements. The higher ionization energies of Group 12 elements result from the saturation of their d orbitals, limiting their electropositivity.

Mercury is relatively less abundant in the Earth's crust and is typically found in minerals like cinnabar, cordierite, and livingstonite, with HgS being the most prevalent mercury ore. Mercury is extracted by burning HgS, following the reaction:

$HgS + O_2 \rightarrow Hg + SO_2$

This process is commonly performed by heating cinnabar in an air stream, concentrating the mercury vapor.
Iron is essential to life, while mercury and chlorine (Cl) are non-essential and highly toxic. These metals, along with cadmium, are typically sourced from sulfides or oxides (e.g., ZnO with carbon). Cadmium is used for corrosion-resistant coatings, and these metals generally have lower boiling and melting points compared to Group 2 elements, with mercury (the only metal that is liquid at room temperature, 25°C) being particularly notable.
While zinc and cadmium are more reactive than mercury, they dissolve in non-oxidizing acids and form thin oxide films when exposed to air. Mercury, on the other hand, oxidizes at room temperature, and its oxide (HgO) readily decomposes when heated. Historically, this decomposition was crucial to the discovery of oxygen. Additionally, mercury can dissolve other metals, particularly those in the +2 oxidation state, and is used as a reference agent in various chemical processes.

6.3 M ll Solution Chemistry

Mercury(II) (Hg^{2+}) is highly protolyzed and precipitates as easily as HgO unless coordinating ligands are present. Mercury ions can form strong complexes, particularly with tetrahedral structures such as $[ML_4]$ (e.g., $[HgCl_4]^{2-}$), and various ligands (L) show different binding affinities, as detailed in the corresponding tables. There is a general trend in complex stability, with elements in the soft-acid-soft-base (class B) category—such as Zn, Cd, and Hg—becoming more stable as you move from Zn to Cd to Hg.[3]
Mercury(II) complexes are among the strongest complexes formed, with high stability constants compared to other elements. These complexes can take different structural forms, including tetrahedral $[ML_4]$, linear $[HgL_2]$, and sometimes even $[HgL_3]$. In solid-state coordination, the size of the Hg^{2+} ion allows for larger coordination numbers, often leading to six or even eight, reflecting the ability of mercury to form covalent bonds with its ligands due to the large ionic radius of Hg^{2+}.

6.4 M ll Solid Citrus

Several aspects of the structures, properties, and solubilities of different compounds involving metals like zinc (Zn), cadmium (Cd), and mercury (Hg).
1. **Fluorides and Ionic Compounds**: Fluorides tend to form well-defined structures and possess properties typical of ionic compounds when the cation size is appropriate. For example, ZnF_2 forms a rutile structure, and other compounds like fluorites exhibit similar ionic characteristics.
2. **Coordination Numbers**: Different metals exhibit different coordination numbers:
   - Zinc (Zn) typically has a coordination number of four.
   - Cadmium (Cd) also has a coordination number of four.
   - Mercury (Hg) can exhibit coordination numbers of two or four, depending on the compound.
3. **Mercury Halides**: The symmetry of mercury halides (HgX_2) can vary:
   - $HgCl_2$ has a molecular structure, meaning it behaves like a molecule rather than a polymer.

- Other mercury halides tend to form more polymeric structures.
- These halides generally have low solubility in water, but solubility increases significantly with temperature, forming inseparable HgX_2 molecules.

4. **Oxides and Sulfides**: Among the oxides and sulfides, only CdO adopts the eight-coordinate rock salt structure typically seen in group II elements. However, CdO is often deficient in oxygen and electrons, which imparts metallic properties to the compound. Zinc oxide (ZnO) and zinc sulfide (ZnS) are notable for their tetrahedral coordination structures, such as those found in wurtzite and mixed zeolite (or cephalate) structures. Interestingly, ZnS can also adopt a structure similar to CdS and CdSe.
5. **Mercury Oxide and Sulfide**: Mercury oxide (HgO) and mercury sulfide (HgS) feature two-coordinated linear chain structures with mercury at the center.
6. **Complex Formation**: The general equilibrium constant for the formation of some metal-ligand complexes (ML4) can be referenced through the value of the log10 β4, indicating the stability of the complex.[1]

Table 1. The general equilibrium constant (log10β4) for the formation of some complexes (ML4)

$\log_{10}\beta_4$			
Hg^{2+}	Cd^{2+}	Zn^{2+}	لیگاند (L)
15	3	0	Cl^-
21	4	−1	Br^-
30	6	−2	I^-
19	7	9	NH_3
41	19	21	CN^-

(7:263).

The oxidation states and complex formation of mercury, as well as its behavior in different chemical environments.

- **Mercury's Oxidation States and Stability**: The +1 oxidation state of mercury (Hg) is stable and is associated with a dimeric ion [Hg-Hg] $^{+2}$. This ion undergoes disproportionation reactions where it converts into mercury (Hg) and Hg^{+2} ions.
- **Dimeric Structure and Magnetic Properties**: The Hg_2^{+2} ion in solid and liquid form shows unique properties, including magnetic behavior and the presence of unpaired electrons, which could contribute to its distinctive spectroscopic characteristics (like the Roman spectrum mentioned).
  $Hg_2^{+2}{}_{(aq)} \rightarrow Hg_{(I)} + Hg^{+2}{}_{(aq)}$
- **Electrochemical Equilibrium**: The equilibrium between Hg_2^{+2} and Hg^{+2} in an aqueous solution has been studied electrochemically, with the equilibrium constant at 25°C given as 0.011. This suggests that Hg_2^{+2} does not exist in high concentrations in solution under standard conditions.
- **Effect of Ligands**: Ligands like sulfide (S_2-) and cyanide (CN-) are mentioned to influence the disproportionation of Hg_2^{+2} by stabilizing one of the oxidation states

(e.g., Hg^{+2}), shifting the equilibrium. It also talks about $HgCl_2$ (mercury(II) chloride) and its linear molecular structure, where Hg is coordinated by chloride ions in a linear arrangement.

- **Formation of Mercury Chains**: When mercury reacts with AsF_5, it forms linear mercury chains (Hg_3^{+2} and Hg_4^{+2}) that lead to the formation of metal compounds such as $Hg0_{33}AsF_6$. This illustrates how mercury's chemistry can vary significantly based on its ligands and oxidation states.
- **Comparison to Zinc and Cadmium**: Zinc (Zn) and cadmium (Cd) are compared to mercury in terms of their behavior in complex formation. Like mercury, these elements form similar complexes, but their smaller ionic size results in more stable lattice energies, which affects their chemical properties.

The mention of "citrus fruits" seems a bit out of place in this context, as it's unclear how they connect to mercury chemistry. It could be a misinterpretation or an incorrect reference. Otherwise, the chemistry of mercury is highly intricate, and this passage provides a glimpse into the complexities of its ionic and molecular behaviors in different chemical environments.

6.5 Organometallic Citrus

Mercury Compounds and Their Interactions in Aqueous Solutions

Mercury (Hg) compounds tend to interact less with environmental factors, making their Hg-O interactions weaker compared to those of zinc (Zn) and cadmium (Cd). These mercury compounds are important in the preparation of organometallic complexes for other elements and can yield water-soluble ions such as $[CH_3Hg]^+$, which serves as a prototype soft acid in the Hard and Soft Acids and Bases (HSAB) theory. All organic mercury compounds are highly toxic because they can cross cell membranes more easily than inorganic ones.

Tahira (2012) explored the potential replacement of water (H_2O) by chloride ions (Cl^-) in the $[Hg(H_2O)_6]^{2+}$ complex in aqueous solutions. This exchange process occurs in a series of steps as shown below:

(i) $[Hg(H_2O)_6]^{2+}(aq) + Cl^- \leftrightarrow [HgCl(H_2O)_5]^{+}$ (aq)

Octaheral Octahedral

(ii) $[HgCl(H_2O)_5]^{+}(aq) + Cl^- \leftrightarrow [HgCl_2(H_2O)_4]$ (aq)

Octahedral trans Octahedral

(ii) $[Hg(H_2O)_6]^{2+}(aq) + Cl^- \leftrightarrow [HgCl(H_2O)_5]^{+}$ (aq)

Trans octahedral tetrahedral

(iv) $[Hg(H_2O)_6]^{2+}(aq) + Cl^- \leftrightarrow [HgCl(H_2O)_5]^{+}$ (aq)

tetrahedral tetrahedral

These reactions reflect the gradual substitution of water molecules by chloride ions. In interactions (ii) and (iv), the coordination number of mercury decreases from 6 to 4. This

occurs because the covalent radius of the oxygen atom is smaller than the ionic radius of chloride, creating space for chloride ions to bind to mercury instead of water molecules.

- In interactions (i) and (ii), the coordination number of Hg remains 6, as chloride ions are smaller compared to the two larger chloride ions involved in later interactions.
- In interactions (iii) and (iv), when two chloride ions (which are heavier) act as ligands, the coordination number decreases to 4. This is due to the steric hindrance caused by the size of the chloride ions and the electrostatic repulsion between the negatively charged chloride ions.

Furthermore, the experimental data suggests that the stability constants follow the order: $k_1 > k_2 > k_3 > k_4$. This order indicates that the stability of the complex $[HgCl_2(H_2O)_4]$ is higher than that of $[HgCl_3(H_2O)]^-$, which cannot be explained purely by statistical factors. The higher stability of $[HgCl_2(H_2O)_4]$ is attributed to differences in the coordination number of Hg^{2+}, the hybridization of Hg orbitals, and the geometric structure of the two complex ions. All these factors, in addition to the statistical factor, contribute to the enhanced stability of $[HgCl_2(H_2O)_4]$.

6.6 Types of Mercury

Mercury exists in various forms, each with its own characteristics and uses. Below are some notable types of mercury:

1. **Red Mercury**: This is often described as a red liquid with explosive properties. It is supposedly one of the isotopes of mercury, believed to be used in the creation of atomic bombs as a neutron source. Red mercury is also rumored to trigger nuclear fission, releasing significant amounts of energy. However, much of this is based on unverified claims, and there's no solid evidence supporting its use in nuclear technology.[6]
2. **Bat Mercury**: Found in caves where bats reside, bat mercury is surrounded by myths and rumors about its purported healing effects. Despite these claims, it is often sold at inflated prices online. The actual chemical composition and the basis for these rumors are unclear, and it's important to be skeptical of such claims.[6]
3. **Plumb**: This is an ancient device that resembles a cone, connected to a rope. It was believed to help in treasure hunting by detecting metal deposits underground. Mercury would be placed in the conical chamber, and as the cone moved, it was supposed to react to the force of metals buried in the earth, indicating the presence of treasure. This practice is now considered more myth than reality.[6]
4. **Cinnabar (HgS)**: A naturally occurring red mercury compound, cinnabar is toxic due to its mercury content. While it does not have explosive properties, its use in ancient times was widespread for artistic and ceremonial purposes, despite its dangerous effects. It's primarily known for its use as a pigment.[1]
5. **Mercury Fulminate ($Hg(CNO)_2$)**: A highly sensitive explosive compound, mercury fulminate is used in detonators and some types of ammunition cartridges. It is a shock-sensitive substance, and its volatility makes it highly dangerous.[1]

6.7 What to Do If Mercury Enters the Body

Mercury is a heavy metal and can enter the human body through various means, including contaminated food or environmental exposure. Prolonged exposure can lead to mercury poisoning, which can be harmful to organs and the nervous system.

If mercury is ingested or absorbed into the body, some methods to counteract its effects include:

- **Dietary Measures**: Consuming foods that help neutralize mercury's toxic effects is recommended. These include dairy products, fish such as green mullet, kilka fish (black herring), sardines, and various vegetables.
- **Nutrient Support**: Specific nutrients like Vitamin E and selenium are known to help mitigate the damage caused by mercury. Other beneficial foods include legumes, egg yolks, dark green leafy vegetables, and eggplant, as they contain compounds that may help detoxify the body.

If mercury exposure is suspected, seeking medical advice and potential treatment (like chelation therapy) is important for minimizing health risks.

6.8 Symptoms of contact with mercury

Mercury exposure can lead to both acute and chronic health issues, depending on the duration and form of contact. Initially, symptoms may be mild but can worsen significantly with prolonged exposure.

6.9 Early Symptoms of Mercury Exposure

- **Vision problems**: Poor or blurred vision.
- **Skin irritation**: Burning sensations, itching, and rashes.
- **Oral symptoms**: Mouth sores, gum inflammation, and excessive drooling.

Later and More Severe Symptoms

- **Neurological effects**: Numbness, tremors, and lack of coordination.
- **Sensory loss**: Loss of vision and hearing.
- **Mental health issues**: Depression, anxiety, confusion, aggression, and giddiness.
- **Respiratory issues**: Shortness of breath, persistent cough, chest congestion, asthma, and bronchitis.

Chronic exposure can also lead to **cognitive issues** like memory problems and speech difficulties, particularly due to the inhalation of mercury vapors.

6.10 Detection and Precautions:

If you experience any symptoms after exposure to mercury, it's critical to stop contact immediately and seek medical help. Blood and urine tests can help assess mercury levels in your body.

Mercury is naturally present in the Earth's crust and is released into the environment through natural processes like volcanic activity and rock weathering, as well as human activities.

6.11 Special Considerations Regarding "Red Mercury"

"Red mercury" is often referenced in discussions about nuclear materials and is said to be used in nuclear fission interactions. While it is associated with dangerous applications, such as facilitating uranium-235 storage, there is controversy about its existence and uses. It is claimed to be an isotope of mercury, but its properties and availability are not well-documented, making it a topic of significant myth and misinformation.[3]

In any case, mercury is extremely hazardous and requires careful handling, especially in occupational or industrial settings. Always prioritize safety and seek immediate medical attention if exposed.

7. Application of Mercury

7.1 Mercury: Historical Uses and Modern Applications

Mercury, a toxic metal with a long history of use, was once incorporated in ancient Greek ointments and Roman cosmetics, where it was believed that all materials were derived from this element. In the 18th and 19th centuries, mercury was widely used in the process of removing animal hair for felt hat production, causing brain damage in workers due to prolonged exposure.

In modern industries, mercury is primarily used in the production of industrial chemicals, electrical and electronic devices, and thermometers designed for high temperatures. Mercury fulminate, a compound of mercury, is used in explosives, while mercury sulfide serves as a pigment in pressure gauges, diffusion pumps, and laboratory equipment.

Mercury is also commonly found in electronics, including switches, fluorescent lamps, and batteries, where it is used as a conductor, along with metals like copper, nickel, cobalt, and lithium. Although mercury's use has diminished due to its toxicity, recycling it from devices like old thermometers, pressure gauges, and lamps remains a profitable industry, enabling valuable metals to re-enter the production cycle.

Despite its historical applications, mercury's use has decreased significantly due to its high toxicity. Alternatives such as copper, nickel, and gold are now more commonly used in electronics. Additionally, red mercury (HgS), once thought to be a rare and valuable substance with explosive properties, is not explosive and is now largely obsolete in favor of safer materials.

Mercury compounds, such as mercuric oxide, have been used for purposes ranging from skin disinfection to insecticide production. Amalgams—mixtures of mercury with other metals like tin and copper—are used in dental fillings due to their durability and strength. Mercury-based compounds, such as calomel, were historically used in medicine to treat skin rashes, but such uses have been phased out as safer alternatives were developed.

Mercury remains a key component in certain thermometers and pressure gauges, although the use of colored alcohol thermometers is becoming more common due to their safety and accuracy. However, the toxicity of mercury necessitates caution in its handling. Prolonged exposure or accidental ingestion can lead to severe health issues, including brain damage and death. As such, careful containment and proper disposal of mercury are crucial to prevent environmental contamination and health risks[3],[4],[8].

8. Findings

Mercury is a fascinating and unique element, with properties and uses that make it stand out.

8.1 Mercury (Hg) Overview

- **Occurrence and Forms:** Mercury exists naturally both in its pure elemental form and as a compound. The most significant mineral form is *red shangarf* (HgS), and it is the only metal that is liquid at room temperature, often referred to as "liquid silver" due to its shiny, silver-like appearance.[3]
- **Amalgamation:** Mercury has the unique ability to dissolve other metals (except iron), forming an alloy known as an amalgam.
- **Liquid State at Room Temperature:** Mercury is one of only two elements (the other being bromine) that are liquid at room temperature (25°C).
- **Reactivity:** While mercury does not react with many acids, such as sulfuric acid, it is capable of dissolving oxidizing acids like sulfuric acid and nitric acid.
- **Mercury (II) Compounds:** Mercury typically forms ionic compounds with highly electronegative ions, including sulfide (HgS), nitride, and fluoride. Its ability to form these compounds is influenced by its relatively low acid strength, especially when compared to metals like zinc or cadmium.
- **Types of Mercury:** Some of the different types of mercury include *red mercury*, *bat mercury*, and *plum mercury*.

8.2 Uses of Mercury

- **Industrial Applications**
  - Mercury compounds are utilized in a range of industries for various purposes, such as producing mercuric oxide for skin disinfectants and insecticides.
  - It is used in thermometers, pressure gauges, diffusion pumps, and other devices like switches and certain types of batteries.
- **Gold Extraction:** Mercury is employed in the preparation of gold, as it is capable of forming amalgams with gold, aiding in the extraction process.

8.3 Health Hazards and Toxicity

- **Toxic Effects:** Exposure to mercury can lead to a variety of harmful health effects, including:
  - Psychological symptoms such as depression, anxiety, and confusion.
  - Physical symptoms like aggression, gout, chronic respiratory disorders (e.g., asthma, bronchitis), and neurological issues such as numbness in hands and feet, and problems with memory, speech, hearing, and vision.

Due to its toxicity, it is crucial to minimize mercury usage and replace it with safer alternatives.

- **Safer Alternatives:** Less toxic metals, such as copper, nickel, cobalt, and lithium, are often used as substitutes in industrial applications, especially for electrical devices.

8.4 Prevention and Protection

- **Dietary Recommendations:** Experts suggest that certain foods can help mitigate the effects of mercury exposure. Consuming dairy products, green mullet, kilka fish (black herring), sardines, and various vegetables can help prevent mercury toxicity.

By understanding both the valuable uses and the dangers associated with mercury, we can make more informed choices regarding its handling and find safer alternatives when possible.

9. Conclusion

9.1 Mercury Overview and Environmental Impact

Mercury is a metallic element that is liquid at room temperature, with a silvery-white appearance. It is often referred to as "liquid silver" and exists in both pure and compound forms. The most important mineral form of mercury is cinnabar (HgS). Mercury can be extracted from its sulfide and oxide forms.

Due to its toxicity, mercury poses significant environmental and health risks. One key approach to reducing these risks is replacing mercury with safer alternatives, which are available for many products that traditionally contain mercury. For instance, mercury is widely used in thermometers, pressure gauges, steam lamps, switches, insecticides, and various other applications.

Water has no significant effect on mercury, but it dissolves all other metals, except iron, forming alloys called amalgams. Amalgams are commonly used in industry, particularly those combining mercury with silver, copper, indium, tin, and zinc. A special amalgam of mercury and gold is also extracted from ore.

9.2 Health Effects of Mercury Exposure

Breathing in mercury vapors or prolonged exposure to mercury can lead to a range of serious health issues. These include depression, anxiety, confusion, aggression, and gout. It can also cause chronic respiratory problems such as asthma, bronchitis, chest congestion, shortness of breath, persistent cough, and bad breath. Additional symptoms may include numbness in the hands and feet, and impairments in memory, speech, hearing, and vision.

10. Acknowledgement and Suggestions

Mercury is a naturally occurring element that is toxic, and its use in various sectors such as industry, medicine, agriculture, and technology requires careful management to prevent harm. It is crucial to exercise precision and caution when handling mercury to minimize its risks. In many instances, safer alternatives to mercury-based products are available and should be prioritized.

In environments like laboratories or industrial factories where mercury is used or handled, substances such as vitamin E and selenium (Se) are important. These compounds can help neutralize the toxic effects of mercury on the body and should be readily available to protect workers and others who may be exposed to mercury. By adopting such safety measures and alternatives, we can reduce the harmful impacts of mercury on health and the environment.

References

[1] P. E. Books, *Non-organic chemistry*, 2nd ed., Translated by M. Laila, Kabul: Ministry of Higher Education, 1401, pp. 260–264.

[2] A. Duffy, *General inorganic chemistry*, Translated by J. Sabunchi, Hamedan: Bo Ali Sina University, B.T., pp. 183–186.

[3] O. Giola, *The chemistry of mineral quality analysis*, Vakol, Ch. 6, Translated by A. Azadeh and F. Logical, Iran University of Science and Technology: Publishing Center, 1376, p. 95.

[4] N. M. Hossaini, *Inorganic chemistry C-1*, Kabul: Navisa Publishing House, 2016, pp. 259–260.

[5] S. M. Mosamim, *General chemistry*, Kabul: White Printing and Press, 2018, p. 105.

[6] S. M. Nahalgar, *Basic principles of chemistry*, Kabul: Hamid Publishing Center, 2006, p. 169.

[7] S. Samargol, *General chemistry for everyone*, Peshawar: Mahan Publishing Center, 2011, pp. 314–315.

[8] N. Tahira, *Inorganic chemistry III*, Translated by N. Tahira, Kabul: Saeed Publications, 2012, pp. 55–56.

Author Profile

Laila Mia Qadiri graduated from the Department of Chemistry in the Faculty of Natural Science at Kabul Pedagogical Institute. I started lecturing at a pedagogical institute and then I started work as a lecturer in the Department of Chemistry Natural Science faculty of Kabul Educational University. I earned my master's degree from Kabul Educational University in 2008. I have 18 research works, including a master's thesis, inorganic chemistry and organic chemistry Published by the Ministry of Higher Education, chemistry teaching methods, three international articles, and domestic articles published in Payam-e-Marafet.