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Article Discussion

Read Edit

Thallium

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Not to be confused with Thulium or Thorium.

Thallium (ⁱ/ˈθæliəm/ *THAL-ee-əm*) is a chemical element with the symbol **Tl** and atomic number 81. This soft gray *poor metal* resembles *tin* but discolors when exposed to air. The two chemists *William Crookes* and *Claude-Auguste Lamy* discovered thallium independently in 1861 by the newly developed method of *flame spectroscopy*. Both discovered the new element in residues of *sulfuric acid* production.

Approximately 60–70% of thallium production is used in the *electronics industry*, and the remainder is used in the *pharmaceutical industry* and in *glass manufacturing*.^[2] It is also used in *infrared detectors*. Thallium is highly *toxic* and was used in *rat poisons* and *insecticides*. Its use has been reduced or eliminated in many countries because of its nonselective toxicity. Because of its use for *murder*, thallium has gained the nicknames "The Poisoner's Poison" and "Inheritance Powder" (alongside *arsenic*).^[3]

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Characteristics

[edit]

Thallium is extremely soft and malleable and can be cut with a knife at room temperature. It has a metallic luster, but when exposed to air, it quickly tarnishes with a bluish-gray tinge that resembles lead. It may be preserved by immersing it in oil. A heavy layer of oxide builds up on thallium if left in air. In the presence of water, thallium *hydroxide* is formed. Sulfuric and *nitric acid* dissolve thallium rapidly to make the *sulfate* and *nitrate* salts, while *hydrochloric acid* forms an insoluble *thallium(I) chloride* layer.^[4] Its *standard electrode potential* is −0.34, slightly higher than the potential for *iron* (at −0.44).

Isotopes

[edit]

Main article: Isotopes of thallium

Thallium has 25 *isotopes* which have *atomic masses* that range from 184 to 210. ²⁰³Tl and ²⁰⁵Tl are the only stable isotopes, and ²⁰⁴Tl is the most stable *radioisotope*, with a *half-life* of 3.78 years.^[5]

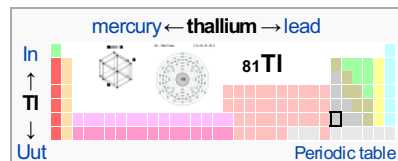
²⁰²Tl (half-life 12.23 days) can be made in a *cyclotron*,^[6] while ²⁰⁴Tl is made by the *neutron activation* of stable thallium in a *nuclear reactor*.^{[5][7]}

²⁰¹Tl (half-life 73 hrs), decays by electron capture, emitting Hg X-rays (~70–80 keV), and photons of 135 and 167 keV in 10% total abundance;^[5] therefore it has good imaging characteristics without excessive patient radiation dose. It is the most popular isotope used for thallium nuclear *cardiac stress tests*.^[8]

Chemistry

[edit]

See also Category: Thallium compounds. The two main *oxidation states* of thallium are +1 and +3. In the oxidation state +1 most compounds closely resemble the corresponding *potassium* or *silver* compounds (The *ionic radius* of thallium(I) is 1.47 Å while that of potassium is 1.33 Å and that of silver is 1.26 Å). For example, the water-soluble and very basic *thallium(I) hydroxide* reacts with *carbon dioxide* forming water-soluble *thallium carbonate*. This carbonate is the only water soluble heavy metal carbonate. The similarity



Appearance															
silvery white															
General properties															
Name, symbol, number	thallium, Tl, 81														
Pronunciation	/ˈθæliəm/ <i>THAL-ee-əm</i>														
Element category	post-transition metal														
Group, period, block	13, 6, p														
Standard atomic weight	204.3833														
Electron configuration	[Xe] 4f ¹⁴ 5d ¹⁰ 6s ² 6p ¹														
Electrons per shell	2, 8, 18, 32, 18, 3 (Image)														
Physical properties															
Phase	solid														
Density (near r.t.)	11.85 g·cm ^{−3}														
Liquid density at m.p.	11.22 g·cm ^{−3}														
Melting point	577 K, 304 °C, 579 °F														
Boiling point	1746 K, 1473 °C, 2683 °F														
Heat of fusion	4.14 kJ·mol ^{−1}														
Heat of vaporization	165 kJ·mol ^{−1}														
Molar heat capacity	26.32 J·mol ^{−1} ·K ^{−1}														
Vapor pressure															
	<table border="1"> <tr> <th>P (Pa)</th> <td>1</td> <td>10</td> <td>100</td> <td>1 k</td> <td>10 k</td> <td>100 k</td> </tr> <tr> <th>at T (K)</th> <td>882</td> <td>977</td> <td>1097</td> <td>1252</td> <td>1461</td> <td>1758</td> </tr> </table>	P (Pa)	1	10	100	1 k	10 k	100 k	at T (K)	882	977	1097	1252	1461	1758
P (Pa)	1	10	100	1 k	10 k	100 k									
at T (K)	882	977	1097	1252	1461	1758									
Atomic properties															
Oxidation states	3, 1 (mildly <i>basic oxide</i>)														
Electronegativity	1.62 (Pauling scale)														
Ionization energies	1st: 589.4 kJ·mol ^{−1} 2nd: 1971 kJ·mol ^{−1} 3rd: 2878 kJ·mol ^{−1}														
Atomic radius	170 pm														
Covalent radius	170±8 pm														
Van der Waals radius	196 pm														
Miscellanea															
Crystal structure	hexagonal														
Magnetic ordering	diamagnetic ^[1]														
Electrical resistivity	(20 °C) 0.18 μΩ·m														
Thermal conductivity	46.1 W·m ^{−1} ·K ^{−1}														
Thermal expansion	(25 °C) 29.9 μm·m ^{−1} ·K ^{−1}														
Speed of sound (thin rod)	(20 °C) 818 ms ^{−1}														
Young's modulus	8 GPa														
Shear modulus	2.8 GPa														
Bulk modulus	43 GPa														
Poisson ratio	0.45														

Myers ex rel. L.M. v. U.S., No. 09-56092 archived on August 22, 2011

لوبان
 Magyar
 Македонски
 മലയാളം
 मराठी
 Bahasa Melayu
 Nederlands
 日本語
 Norsk (bokmål)
 Norsk (nynorsk)
 Occitan
 پنجابی
 Polski
 Português
 Română
 Runa Simi
 Русский
 Seeltersk
 Sicilianu
 Simple English
 Slovenčina
 Slovenščina
 Српски / Srpski
 Srpskohrvatski / Српскохрватски
 Suomi
 Svenska
 தமிழ்
 ไทย
 Türkçe
 Українська
 اردو
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 Winaray
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 Yorùbá
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 中文

with silver compounds is observed with the halide, oxide, and sulfide compounds. **Thallium(I) bromide** is a photosensitive yellow compound very similar to the **silver bromide**, while the black **thallium(I) oxide** and **thallium(I) sulfide** are very similar to the **silver oxide** and **silver sulfide**.

The compounds with oxidation state +3 resemble the corresponding aluminium(III) compounds. They are moderately strong oxidizing agents, as illustrated by the reduction potential of +0.72 volts for $Tl^{3+} + 3 e^{-} \rightarrow Tl(s)$. The thallium(III) oxide is a black solid which decomposes above 800 °C, forming the thallium(I) oxide and oxygen.^[4]

History

[[edit](#)]

Thallium (*Greek* *θαλλός*, *thallos*, meaning "a green shoot or twig")^[9] was discovered by flame spectroscopy in 1861.^[10] The name comes from thallium's bright **green** spectral emission lines.^[11]

After the publication of the improved method of flame spectroscopy by **Robert Bunsen** and **Gustav Kirchhoff**^[12] and the discovery of **caesium** and **rubidium** in the years 1859 to 1860, flame spectroscopy became an approved method to determine the composition of minerals and chemical products. **William Crookes** and **Claude-Auguste Lamy** both started to use the new method. William Crookes used it to make spectroscopic determinations for **tellurium** on selenium compounds deposited in the **lead chamber** of a sulfuric acid production plant near **Tilkerode** in the **Harz mountains**. He had obtained the samples for his research on selenium cyanide from **August Hofmann** years earlier.^{[13][14]} By 1862, Crookes was able to isolate small quantities of the new element and determine the properties of a few compounds.^[15] Claude-Auguste Lamy used a similar spectrometer to Crookes' to determine the composition of a selenium-containing substance which was deposited during the production of **sulfuric acid** from **pyrite**. He also noticed the new green line in the spectra and concluded that a new element was present. Lamy had received this material from the sulfuric acid plant of his friend **Fréd Kuhlmann** and this by-product was available in large quantities. Lamy started to isolate the new element from that source.^[16] The fact that Lamy was able to work ample quantities of thallium enabled him to determine the properties of several compounds and in addition he prepared a small ingot of metallic thallium which he prepared by remelting thallium he had obtained by electrolysis of thallium salts.

As both scientists discovered thallium independently and a large part of the work, especially the isolation of the metallic thallium was done by Lamy, Crookes tried to secure his priority on the work. Lamy was awarded a medal at the International Exhibition in London 1862: *For the discovery of a new and abundant source of thallium* and after heavy protest Crookes also received a medal: *thallium, for the discovery of the new element*. The controversy between both scientists continued through 1862 and 1863. Most of the discussion ended after Crookes was elected **Fellow of the Royal Society** in June 1863.^{[17][18]}

The dominant use of thallium was the use as poison for **rodents**. After several accidents the use as poison was banned in the United States by the **Presidential Executive Order** 11643 in February 1972. In the subsequent years several other countries also banned the use.^[19]

Occurrence and production

[[edit](#)]

Although thallium is a modestly abundant element in the Earth's crust, with a concentration estimated to be about 0.7 mg/kg,^[20] mostly in association with **potassium**-based **minerals** in **clays**, **soils**, and **granites**, thallium is not generally economically recoverable from these sources. The major source of thallium for practical purposes is the trace amount that is found in **copper**, **lead**, **zinc**, and other heavy-metal-sulfide ores.^{[21][22]}



Crystals of **hutchinsonite** (TlPbAs₅S₉)

Thallium is found in the minerals **crookesite** TICu₇Se₄, **hutchinsonite** TlPbAs₅S₉, and **lorandite** TlAsS₂.^[23] Thallium also occurs as a trace element in **iron pyrite**, and thallium is extracted as a by-product of roasting this mineral for the production of **sulfuric acid**.^{[2][24]}

Thallium can also be obtained from the **smelting** of lead and zinc ores. **Manganese nodules** found on the **ocean floor** also contain some thallium, but the collection of these nodules has been and continues to be prohibitively expensive. There is also the potential for damaging the environment of the oceans.^[25] In addition, several other thallium minerals, containing 16% to 60% thallium, occur in nature as complexes of sulfides or selenides that primarily contain **antimony**, **arsenic**, copper, lead, and/or **silver**. However, these minerals are rare, and they have had no commercial importance as sources of thallium.^[20] The **Allchar deposit** in southern **Macedonia** was the only area where thallium was ever actively mined. This deposit still

contains a loosely estimated 500 tonnes of thallium, and it is a source for several rare thallium minerals, for example **lorandite**.^[26]

The **United States Geological Survey** (USGS) estimates that the annual worldwide production of thallium is about 10 metric tonnes as a by-product from the smelting of copper, zinc, and lead ores.^[20] Thallium is either extracted from the dusts from the smelter flues or from residues such as **slag** that are collected at the end of the smelting process.^[20] The raw materials used for thallium production contain large amounts of other materials and therefore a purification is the first step. The thallium is leached either by the use of a base or sulfuric acid from the material. The thallium is several times precipitated from the solution and to remove further impurities. At the end it is converted to thallium sulfate and the thallium is extracted by **electrolysis** on **platinum** or **stainless steel** plates.^[24] The production of thallium decreased by about 33% in the period from 1995 to 2009 – from about 15 metric **tonnes** to about 10 tonnes. Since there are several small deposits or ores with relatively high thallium content, it would be possible to increase the production of it if a new application, such as a hypothetical thallium-containing **high-temperature superconductor**, becomes practical for widespread use outside of the laboratory.^[20]

Applications

[[edit](#)]

Historic uses

[[edit](#)]

The **odorless** and **tasteless thallium sulfate** was once widely used as **rat poison** and **ant** killer. Since 1972 this use has been prohibited in the **United States** due to safety concerns.^[19] Many other countries followed this example in the following years.^[2] Thallium salts were used in the treatment of **ringworm**, other **skin infections** and to reduce the **night sweating** of **tuberculosis** patients. However this use has been limited due to their narrow **therapeutic index**, and the development of more-advanced medicines for these conditions.^{[27][28][29]}

Mohs hardness	1.2																														
Brinell hardness	26.4 MPa																														
CAS registry number	7440-28-0																														
Most stable isotopes																															
Main article: Isotopes of thallium																															
<table> <tbody><tr> <th>iso</th> <th>NA</th> <th>half-life</th> <th>DM</th> <th>DE (MeV)</th> <th>DP</th> </tr> <tr> <td>²⁰³Tl</td> <td>29.524%</td> <td>²⁰³Tl is stable with 122 neutrons</td> <td></td> <td></td> <td></td> </tr> <tr> <td>²⁰⁴Tl</td> <td>syn</td> <td>119 Ms (3.78 y)</td> <td>β[−]</td> <td>0.764</td> <td>²⁰⁴Pb</td> </tr> <tr> <td></td> <td></td> <td></td> <td>ε</td> <td>0.347</td> <td>²⁰⁴Hg</td> </tr> <tr> <td>²⁰⁵Tl</td> <td>70.476%</td> <td>²⁰⁵Tl is stable with 124 neutrons</td> <td></td> <td></td> <td></td> </tr> </tbody></table>	iso	NA	half-life	DM	DE (MeV)	DP	²⁰³ Tl	29.524%	²⁰³ Tl is stable with 122 neutrons				²⁰⁴ Tl	syn	119 Ms (3.78 y)	β [−]	0.764	²⁰⁴ Pb				ε	0.347	²⁰⁴ Hg	²⁰⁵ Tl	70.476%	²⁰⁵ Tl is stable with 124 neutrons				
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Optics

[edit]

Thallium(I) bromide and **thallium(I) iodide crystals** have been used as infrared optical materials, because they are harder than other common infrared optics, and because they have transmission at significantly longer wavelengths. The trade name KRS-5 refers to this material.^[30] **Thallium oxide** has been used to manufacture **glasses** that have a high **index of refraction**. Combined with **sulfur** or **selenium** and **arsenic**, thallium has been used in the production of high-**density** glasses that have low **melting points** in the range of 125 and 150 °C. These glasses have room temperature properties that are similar to ordinary glasses and are durable, insoluble in water and have unique **refractive indices**.^[31]

Electronics

[edit]

Thallium(I) sulfide's **electrical conductivity** changes with exposure to **infrared light** therefore making this compound useful in **photoresistors**.^[27] Thallium selenide has been used in a **bolometer** for infrared detection.^[32] Doping selenium semiconductors with thallium improves their performance, and therefore it is used in trace amounts in selenium rectifiers.^[27] Another application of thallium doping is the **sodium iodide** crystals in **gamma radiation** detection devices. In these, the sodium iodide crystals are doped with a small amount of thallium to improve their efficiency as **scintillation** generators.^[33] Some of the electrodes in **dissolved oxygen analyzers** contain thallium.^[2]



Corroded thallium rod

[edit]

High-temperature superconductivity

Research activity with thallium is ongoing to develop high-temperature **superconducting** materials for such applications as **magnetic resonance imaging**, storage of magnetic energy, **magnetic propulsion**, and **electric power generation** and transmission. The research in applications started after the discovery of the first **thallium barium calcium copper oxide** superconductor in 1988.^[34]

Medical

[edit]

Before the widespread application of **technetium-99m** in **nuclear medicine**, the **radioactive** isotope **thallium-201**, with a half-life of 73 hours, was the main substance for nuclear cardiography. The nuclide is still used for stress tests for risk stratification in patients with **coronary artery disease** (CAD).^[35] This isotope of thallium can be generated using a transportable generator which is similar to the **technetium-99m generator**.^[36] The generator contains **lead-201** (half-life 9.33 hours) which decays by **electron capture** to the thallium-201. The lead-201 can be produced in a **cyclotron** by the bombardment of thallium with **protons** or **deuterons** by the (p,3n) and (d,4n) reactions.^{[37][38]}

Thallium stress test

[edit]

A thallium stress test is a form of **scintigraphy**, where amount of thallium in tissues correlates with tissue blood supply. Viable cardiac cells have normal **Na⁺/K⁺ ion exchange pumps**. The Tl⁺ cation binds the K⁺ pumps and is transported into the cells. Exercise or **dipyridamole** induces widening (**vasodilation**) of normal coronary arteries. This produces **coronary steal** from areas where arteries are maximally dilated. Areas of infarct or **ischemic tissue** will remain "cold". Pre- and post-stress thallium may indicate areas which will benefit from myocardial **revascularization**. Redistribution indicates the existence of coronary steal and the presence of ischemic **coronary artery disease**.^[39]

Other uses

[edit]

A mercury-thallium alloy, which forms a **eutectic** at 8.5% thallium, is reported to freeze at −60 °C, some 20 °C below the freezing point of mercury. This alloy is used in thermometers and low-temperature switches.^[27] In organic synthesis thallium(III) salts, as thallium trinitrate or triacetate, are useful reagents performing different transformations in aromatics, ketones, olefins, among others.^[40] Thallium is a constituent of the alloy in the **anode** plates in magnesium seawater batteries.^[2] Soluble thallium salts are added to **gold plating** baths to increase the speed of plating and to reduce grain size within the gold layer.^[41]

The saturated solution of equal parts of thallium(I) **formate** (Tl(CHO₂)) and thallium(I) **malonate** (Tl(C₃H₃O₄)) in water is known as **Clerici solution**. It is a mobile odorless liquid whose color changes from yellowish to clear upon reducing the concentration of the thallium salts. With the density of 4.25 g/cm³ at 20 °C, Clerici solution is one of the heaviest aqueous solutions known. It was used in the 20th century for measuring density of minerals by the **flotation** method, but the use is discontinued due to the high toxicity and corrosiveness of the solution.^{[42][43]}

Toxicity

[edit]

*Main article: **Thallium poisoning***



Thallium and its compounds are extremely toxic, and should be handled with great care. There are numerous recorded cases of fatal thallium poisoning.^[44] Contact with skin is dangerous, and adequate ventilation should be provided when melting this metal. Thallium(I) compounds have a high aqueous solubility and are readily absorbed through the skin. Exposure to them should not exceed 0.1 mg per m² of skin in an 8-hour time-weighted average (40-hour work week).

Thallium is a suspected human **carcinogen**.^[45] For a long time thallium compounds were easily available as rat poison.

This fact and that it is water soluble and nearly tasteless led to frequent intoxications caused by accident or criminal intent.^[18]

Treatment and internal decontamination

[edit]

One of the main methods of removing thallium (both radioactive and normal) from humans is to use **Prussian blue**, which is a material which absorbs thallium.^[46] Up to 20 g per day of Prussian blue is fed by mouth to the person, and it passes through their digestive system and comes out in the **stool**. **Hemodialysis** and **hemoperfusion** are also used to remove thallium from the blood serum. At later stage of the treatment additional potassium is used to mobilize thallium from the tissue.^{[47][48]}










Thallium pollution

[edit]

According to the **United States Environmental Protection Agency** (EPA), man-made sources of thallium pollution include gaseous emission of **cement factories**, coal burning power plants, and metal sewers. The main source of elevated thallium concentrations in water is the leaching of thallium from ore processing operations.^{[22][49]}

See also

[edit]

Books View or order collections of articles	 Thallium	 Period 6 elements	 Boron group
	 Chemical elements (sorted alphabetically)	 Chemical elements (sorted by number)	
Portals Access related topics	 Chemistry portal		
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External links

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- Toxicity, thallium
- NLM hazardous substances databank – Thallium, elemental
- ATSDR - ToxFAQs

v · d · e Periodic table [hide]

H																	He														
Li	Be											B	C	N	O	F	Ne														
Na	Mg											Al	Si	P	S	Cl	Ar														
K	Ca											Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr				
Rb	Sr											Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe					
Cs	Ba	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Uuq	Uup	Uuh	Uus	Uuo
Alkali metals		Alkaline earth metals		Lanthanides			Actinides			Transition metals			Other metals		Metalloids		Other nonmetals		Halogens		Noble gases		Unknown chem. properties								

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