Bismuth

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Bismuth is a chemical element with the symbol **Bi** and the atomic number 83. Bismuth, a pentavalent post-transition metal and one of the pnictogens, chemically resembles its lighter homologs arsenic and antimony. Elemental bismuth may occur naturally, although its sulfide and oxide form important commercial ores. The free element is 86% as dense as lead. It is a brittle metal with a silvery white color when freshly produced but is often seen in air with a pink tinge owing to surface oxidation. Bismuth is the most naturally diamagnetic element, and has one of the lowest values of thermal conductivity among metals.

Bismuth metal has been known since ancient times, although it was often confused with lead and tin, which share some physical properties. The etymology is uncertain, but possibly comes from Arabic *bi ismid*, meaning having the properties of antimony[3] or the German words *weiße Masse* or *Wismuth* ("white mass"), translated in the mid-sixteenth century to New Latin *bisemutum*.[4]

Bismuth was long considered the element with the highest atomic mass that is stable. However, in 2003 it was discovered to be weakly radioactive: its only primordial isotope, bismuth-209, decays via alpha decay with a half life more than a billion times the estimated age of the universe.[5][6] Because of its tremendously long half-life, bismuth may still be considered stable for almost all purposes.[6]

Bismuth compounds account for about half the production of bismuth. They are used in cosmetics, pigments, and a few pharmaceuticals, notably bismuth subsalicylate, used to treat diarrhea.[6] Bismuth's unusual propensity to expand upon freezing is responsible for some of its uses, such as in casting of printing type.[6] Bismuth has unusually low toxicity for a heavy metal.[6] As the toxicity of lead has become more apparent in recent years, there is an increasing use of bismuth alloys (presently about a third of bismuth production) as a replacement for lead.

Bismuth, $_{83}$Bi

General properties	
Name, symbol	bismuth, Bi
Appearance	lustrous brownish silver
Bismuth in the periodic table	
Atomic number (*Z*)	83
Group, block	group 15 (pnictogens), p-block
Period	period 6
Element category	post-transition metal
Standard atomic weight (±) (A_r)	208.98040(1)[1]
Electron configuration	[Xe] $4f^{14}$ $5d^{10}$ $6s^2$ $6p^3$
per shell	2, 8, 18, 32, 18, 5
Physical properties	
Phase	solid
Melting point	544.7 K (271.5 °C, 520.7 °F)
Boiling point	1837 K (1564 °C,

Characteristics

Physical characteristics

Bismuth crystal illustrating the many iridescent refraction hues of its oxide surface

Bismuth is a brittle metal with a white, silver-pink hue, often occurring in its native form, with an iridescent oxide tarnish showing many colors from yellow to blue. The spiral, stair-stepped structure of bismuth crystals is the result of a higher growth rate around the outside edges than on the inside edges. The variations in the thickness of the oxide layer that forms on the surface of the crystal causes different wavelengths of light to interfere upon reflection, thus displaying a rainbow of colors. When burned in oxygen, bismuth burns with a blue flame and its oxide forms yellow fumes.[13] Its toxicity is much lower than that of its neighbors in the periodic table, such as lead, antimony, and polonium.

Artificially grown bismuth crystal illustrating the stairstep crystal structure, with a 1 cm^3 cube of bismuth metal

No other metal is verified to be more naturally diamagnetic than bismuth.[13][16] (Superdiamagnetism is a different physical phenomenon.) Of any metal, it has one of the lowest values of thermal conductivity (after manganese, and maybe neptunium and plutonium) and the highest Hall coefficient.[17] It has a high electrical resistivity.[13] When deposited in sufficiently thin layers on a substrate, bismuth is a semiconductor, despite being a post-transition metal.[18]

Elemental bismuth is denser in the liquid phase than the solid, a characteristic it shares with antimony, germanium, silicon and gallium.[19] Bismuth expands 3.32% on solidification; therefore, it was long a component of low-melting typesetting alloys, where it compensated for the contraction of the other alloying components,[13][20][21][22] to form almost isostatic bismuth-lead eutectic alloys.

	2847 °F)
Density near r.t.	9.78 g/cm^3
when liquid, at m.p.	10.05 g/cm^3
Heat of fusion	11.30 kJ/mol
Heat of vaporization	179 kJ/mol
Molar heat capacity	25.52 J/(mol·K)

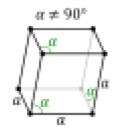
Vapor pressure

P (Pa)	**1**	**10**	**100**	**1 k**	**10 k**	**100 k**
at T (K)	941	1041	1165	1325	1538	1835

Atomic properties

Oxidation states	5, 4, **3**, 2, 1, −1, −2, −3 (a mildly acidic oxide)
Electronegativity	Pauling scale: 2.02
Ionization energies	1st: 703 kJ/mol 2nd: 1610 kJ/mol 3rd: 2466 kJ/mol (more)
Atomic radius	empirical: 156 pm
Covalent radius	148±4 pm
Van der Waals radius	207 pm

Miscellanea

Crystal structure	rhombohedral[2] 
Speed of sound thin rod	1790 m/s (at 20 °C)
Thermal expansion	13.4 µm/(m·K) (at 25 °C)
Thermal	7.97 W/(m·K)

Though virtually unseen in nature, high-purity bismuth can form distinctive, colorful hopper crystals. It is relatively nontoxic and has a low melting point just above 271 °C, so crystals may be grown using a household stove, although the resulting crystals will tend to be lower quality than lab-grown crystals.[23]

At ambient conditions bismuth shares the same layered structure as the metallic forms of arsenic and antimony,[24] crystallizing in the rhombohedral lattice[25] (Pearson symbol hR6, space group $R\bar{3}m$ No. 166), which is often classed into trigonal or hexagonal crystal systems.[2] When compressed at room temperature, this Bi-I structure changes first to the monoclinic Bi-II at 2.55 GPa, then to the tetragonal Bi-III at 2.7 GPa, and finally to the body-centered cubic Bi-IV at 7.7 GPa. The corresponding transitions can be monitored via changes in electrical conductivity; they are rather reproducible and abrupt, and are therefore used for calibration of high-pressure equipment.[26][27]

Chemical characteristics

Bismuth is stable to both dry and moist air at ordinary temperatures. When red-hot, it reacts with water to make bismuth(III) oxide.[28]

$$2\ Bi + 3\ H_2O \rightarrow Bi_2O_3 + 3\ H_2$$

It reacts with fluorine to make bismuth(V) fluoride at 500 °C or bismuth(III) fluoride at lower temperatures (typically from Bi melts); with other halogens it yields only bismuth(III) halides.[29][30][31] The trihalides are corrosive and easily react with moisture, forming oxyhalides with the formula BiOX.[32]

$$2\ Bi + 3\ X_2 \rightarrow 2\ BiX_3\ (X = F, Cl, Br, I)$$

Bismuth dissolves in concentrated sulfuric acid to make bismuth(III) sulfate and sulfur dioxide.[28]

$$6\ H_2SO_4 + 2\ Bi \rightarrow 6\ H_2O + Bi_2(SO_4)_3 + 3\ SO_2$$

It reacts with nitric acid to make bismuth(III) nitrate.

conductivity	
Electrical resistivity	1.29 µΩ·m (at 20 °C)
Magnetic ordering	diamagnetic
Young's modulus	32 GPa
Shear modulus	12 GPa
Bulk modulus	31 GPa
Poisson ratio	0.33
Mohs hardness	2.25
Brinell hardness	70–95 MPa
CAS Number	7440-69-9
History	
Discovery	Claude François Geoffroy (1753)

Most stable isotopes of bismuth

iso	NA	half-life	DM	DE (MeV)	DP
^{207}Bi	syn	31.55 y	β^+	2.399	^{207}Pb
^{208}Bi	syn	3.68×10^5 y	β^+	2.880	^{208}Pb
^{209}Bi	100%	1.9×10^{19} y	α	3.137	^{205}Tl
^{210}Bi	trace	5.012 d	β^-	1.426	^{210}Po
			α	5.982	^{206}Tl
^{210m}Bi	syn	3.04×10^6 y	IT	0.271	^{210}Bi
			α	6.253	^{206}Tl

$$Bi + 6\ HNO_3 \rightarrow 3\ H_2O + 3\ NO_2 + Bi(NO_3)_3$$

It also dissolves in hydrochloric acid, but only with oxygen present.[28]

$$4\ Bi + 3\ O_2 + 12\ HCl \rightarrow 4\ BiCl_3 + 6\ H_2O$$

It is used as a transmetalating agent in the synthesis of alkaline-earth metal complexes:

$$3\ Ba + 2\ BiPh_3 \rightarrow 3\ BaPh_2 + 2\ Bi$$

Isotopes

The only primordial isotope of bismuth, bismuth-209, was traditionally regarded as the heaviest stable isotope, but it had long been suspected[33] to be unstable on theoretical grounds. This was finally demonstrated in 2003, when researchers at the Institut d'Astrophysique Spatiale in Orsay, France, measured the alpha emission half-life of ^{209}Bi to be 1.9×10^{19} years,[34] over a billion times longer than the current estimated age of the universe.[6] Owing to its extraordinarily long half-life, for all presently known medical and industrial applications, bismuth can be treated as if it is stable and nonradioactive. The radioactivity is of academic interest because bismuth is one of few elements whose radioactivity was suspected and theoretically predicted before being detected in the laboratory.[6] Bismuth has the longest known alpha decay half-life, although tellurium-128 has a double beta decay half-life of over 2.2×10^{24} years.[35]

Several isotopes of bismuth with short half-lives occur within the radioactive disintegration chains of actinium, radium, and thorium, and more have been synthesized experimentally. Bismuth-213 is also found on the decay chain of uranium-233.[36]

Commercially, the radioactive isotope bismuth-213 can be produced by bombarding radium with bremsstrahlung photons from a linear particle accelerator. In 1997, an antibody conjugate with bismuth-213, which has a 45-minute half-life and decays with the emission of an alpha particle, was used to treat patients with leukemia. This isotope has also been tried in cancer treatment, for example, in the targeted alpha therapy (TAT) program.[37][38]

Source

- Wikipedia: Bismuth (https://en.wikipedia.org/wiki/Bismuth)