Bromine

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Bromine is a chemical element with symbol **Br** and atomic number 35. It is the third-lightest halogen, and is a fuming red-brown liquid at room temperature that evaporates readily to form a similarly coloured gas. Its properties are thus intermediate between those of chlorine and iodine. Isolated independently by two chemists, Carl Jacob Löwig (in 1825) and Antoine Jérôme Balard (in 1826), its name was derived from the Ancient Greek *βρῶμος* "stench", referencing its sharp and disagreeable smell.

Elemental bromine is very reactive and thus does not occur free in nature, but in colourless soluble crystalline mineral halide salts, analogous to table salt. While it is rather rare in the Earth's crust, the high solubility of the bromide ion (Br^{-}) has caused its accumulation in the oceans. Commercially the element is easily extracted from brine pools, mostly in the United States, Israel and China. The mass of bromine in the oceans is about one three-hundredth of that of chlorine.

At high temperatures, organobromine compounds readily convert to free bromine atoms, a process that stops free radical chemical chain reactions. This effect makes organobromine compounds useful as fire retardants and more than half the bromine produced worldwide each year is put to this purpose. Unfortunately, the same property causes sunlight to convert volatile organobromine compounds to free bromine atoms in the atmosphere, causing ozone depletion. As a result, many organobromide compounds —such as the pesticide methyl bromide—are no longer used. Bromine compounds are still used in well drilling fluids, in photographic film, and as an intermediate in the manufacture of organic chemicals.

Bromine has sometimes been considered to be possibly essential in humans, but with the support of only limited circumstantial evidence, and no clear biological role. As a pharmaceutical, the simple bromide ion (Br^{-}) has inhibitory effects on the central nervous system, and bromide salts were once a major medical sedative, before replacement by shorter-acting drugs. They retain niche uses as antiepileptics.

Properties

Bromine, $_{35}$Br

General properties	
Name, symbol	bromine, Br
Appearance	reddish-brown
Bromine in the periodic table	
Atomic number (*Z*)	35
Group, block	group 17 (halogens), p-block
Period	period 4
Element category	□ diatomic nonmetal
Standard atomic weight (A_r)	79.904[1] (79.901–79.907)[2]
Electron configuration	[Ar] $3d^{10}$ $4s^2$ $4p^5$
per shell	2, 8, 18, 7
Physical properties	
Phase	liquid

Illustrative and secure bromine sample for teaching

Bromine is the third halogen, being a nonmetal in group 17 of the periodic table. Its properties are thus similar to those of fluorine, chlorine, and iodine, and tend to be intermediate between those of the two neighbouring halogens, chlorine and iodine. Bromine has the electron configuration [Ar]$3d^{10}4s^{2}4p^{5}$, with the seven electrons in the fourth and outermost shell acting as its valence electrons. Like all halogens, it is thus one electron short of a full octet, and is hence a strong oxidising agent, reacting with many elements in order to complete its outer shell.[17] Corresponding to periodic trends, it is intermediate in electronegativity between chlorine and iodine (F: 3.98, Cl: 3.16, Br: 2.96, I: 2.66), and is less reactive than chlorine and more reactive than iodine. It is also a weaker oxidising agent than chlorine, but a stronger one than iodine. Conversely, the bromide ion is a weaker reducing agent than iodide, but a stronger one than chloride.[17] These similarities led to chlorine, bromine, and iodine together being classified as one of the original triads of Johann Wolfgang Döbereiner, whose work foreshadowed the periodic law for chemical elements.[18][19] It is intermediate in atomic radius between chlorine and iodine, and this leads to many of its atomic properties being similarly intermediate in value between chlorine and iodine, such as first ionisation energy, electron affinity, enthalpy of dissociation of the X_2 molecule (X = Cl, Br, I), ionic radius, and X–X bond length.[17] The volatility of bromine accentuates its very penetrating, choking, and unpleasant odour.[20]

All four stable halogens experience intermolecular van der Waals forces of attraction, and their strength increases together with number of electrons among all homonuclear diatomic halogen molecules. Thus, the melting and boiling points of bromine are intermediate between those of chlorine and iodine. As a result of the increasing molecular weight of the halogens down the group, the density and heats of fusion and vaporisation of bromine are again intermediate between those of chlorine and iodine, although all their heats of vaporisation are fairly low (leading to high volatility) thanks to their diatomic molecular structure.[17] The halogens darken in colour as the group is descended: fluorine is a very pale yellow gas, chlorine is greenish-yellow, and bromine is a reddish-brown volatile liquid that melts at −7.2 °C and boils at 58.8 °C. (Iodine is a

Melting point	265.8 K (−7.2 °C, 19 °F)
Boiling point	332.0 K (58.8 °C, 137.8 °F)
Density near r.t.	Br_2, liquid: 3.1028 g/cm^3
Triple point	265.90 K, 5.8 kPa[3]
Critical point	588 K, 10.34 MPa[3]
Heat of fusion	(Br_2) 10.571 kJ/mol
Heat of vaporisation	(Br_2) 29.96 kJ/mol
Molar heat capacity	(Br_2) 75.69 J/(mol·K)

Vapour pressure

P (Pa)	**1**	**10**	**100**	**1 k**	**10 k**	**100 k**
at T (K)	185	201	220	244	276	332

Atomic properties

Oxidation states	7, **5**, 4, **3**, **1**, **−1** (a strongly acidic oxide)
Electronegativity	Pauling scale: 2.96
Ionisation energies	1st: 1139.9 kJ/mol 2nd: 2103 kJ/mol 3rd: 3470 kJ/mol
Atomic radius	empirical: 120 pm
Covalent radius	120±3 pm
Van der Waals radius	185 pm

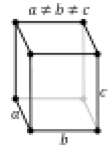
Miscellanea

Crystal structure	orthorhombic

shiny black solid.) This trend occurs because the wavelengths of visible light absorbed by the halogens increase down the group.[17] Specifically, the colour of a halogen, such as bromine, results from the electron transition between the highest occupied antibonding π_g molecular orbital and the lowest vacant antibonding σ_u molecular orbital.[21] The colour fades at low temperatures, so that solid bromine at −195 °C is pale yellow.[17]

Like solid chlorine and iodine, solid bromine crystallises in the orthorhombic crystal system, in a layered lattice of Br_2 molecules. The Br–Br distance is 227 pm (close to the gaseous Br–Br distance of 228 pm) and the Br⋯Br distance between molecules is 331 pm within a layer and 399 pm between layers (compare the van der Waals radius of bromine, 195 pm). This structure means that bromine is a very poor conductor of electricity, with a conductivity of around $5 \times 10^{-13}\ \Omega^{-1}\ \mathrm{cm}^{-1}$ just below the melting point, although this is better than the essentially undetectable conductivity of chlorine.[17]

At a pressure of 55 GPa (roughly 540,000 times atmospheric pressure) bromine undergoes an insulator-to-metal transition. At 75 GPa it changes to a face-centered orthorhombic structure. At 100 GPa it changes to a body centered orthorhombic monatomic form.[22]



Speed of sound	206 m/s (at 20 °C)
Thermal conductivity	0.122 W/(m·K)
Electrical resistivity	7.8×10^{10} Ω·m (at 20 °C)
Magnetic ordering	diamagnetic[4]
CAS Number	7726-95-6

History

Discovery and first isolation	Antoine Jérôme Balard and Carl Jacob Löwig (1825)

Most stable isotopes of bromine

iso	NA	half-life	DM	DE (MeV)	DP
^{79}Br	51%	is stable with 44 neutrons			
^{81}Br	49%	is stable with 46 neutrons			

Isotopes

Bromine has two stable isotopes, ^{79}Br and ^{81}Br. These are its only two natural isotopes, with ^{79}Br making up 51% of natural bromine and ^{81}Br making up the remaining 49%. Both have nuclear spin 3/2− and thus may be used for nuclear magnetic resonance, although ^{81}Br is more favourable. The other bromine isotopes are all radioactive, with half-lives too short to occur in nature. Of these, the most important are ^{80}Br ($t_{1/2}$ = 17.7 min), ^{80m}Br ($t_{1/2}$ = 4.421 h), and ^{82}Br ($t_{1/2}$ = 35.28 h), which may be produced from the neutron activation of natural bromine.[17] The most stable bromine radioisotope is ^{77}Br ($t_{1/2}$ = 57.04 h). The primary decay mode of isotopes lighter than ^{79}Br is electron capture to isotopes of selenium; that of isotopes heavier than ^{81}Br is beta decay to isotopes of krypton; and ^{80}Br may decay by either mode to stable ^{80}Se or ^{80}Kr.[23]

Source

- Wikipedia: Bromine.