# Astatine

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**Astatine** is a radioactive chemical element with the chemical symbol **At** and atomic number 85, and is the rarest naturally occurring element on the Earth's crust. It occurs on Earth as the decay product of various heavier elements. All its isotopes are short-lived; the most stable is astatine-210, with a half-life of 8.1 hours. Elemental astatine has never been viewed because any macroscopic sample would be immediately vaporized by its radioactive heating. It has yet to be determined if this obstacle could be overcome with sufficient cooling.

The bulk properties of astatine are not known with any certainty. Many of these have been estimated based on its periodic table position as a heavier analog of iodine, and a member of the halogens – the group of elements including fluorine, chlorine, bromine, and iodine. It is likely to have a dark or lustrous appearance and may be a semiconductor or possibly a metal; it probably has a higher melting point than that of iodine. Chemically, several anionic species of astatine are known and most of its compounds resemble those of iodine. It also shows some metallic behavior, including being able to form a stable monatomic cation in aqueous solution (unlike the lighter halogens).

Dale R. Corson, Kenneth Ross MacKenzie, and Emilio G. Segrè synthesized the element at the University of California, Berkeley in 1940, naming it after the Greek *astatos* (ἄστατος), "unstable". Four isotopes of astatine were subsequently found in nature, although it is the least abundant of all the naturally occurring elements, with much less than one gram being present at any given time in the Earth's crust. Neither the most stable isotope astatine-210 nor the medically useful astatine-211 occurs naturally. They can only be produced synthetically, usually by bombarding bismuth-209 with alpha particles.

## Characteristics

Astatine is an extremely radioactive element; all its isotopes have short half-lives of 8.1 hours or less, decaying into bismuth, polonium, radon, or other astatine isotopes. Most of its isotopes are very unstable with half-lives of one second or less. Of the first 101 elements in the periodic table, only francium is less stable.[7]

**Astatine, $_{85}$At**

| General properties | |
|---|---|
| **Name, symbol** | astatine, At |
| **Appearance** | unknown, probably metallic |
| **Astatine in the periodic table** | |
| **Atomic number** ($Z$) | 85 |
| **Group, block** | group 17 (halogens), p-block |
| **Period** | period 6 |
| **Element category** | ▯ metalloid, sometimes classified as a nonmetal, or a metal[1][2] |
| **Standard atomic weight** ($A_r$) | (210) |
| **Electron configuration** | [Xe] $4f^{14}$ $5d^{10}$ $6s^2$ $6p^5$ |
| per shell | 2, 8, 18, 32, 18, 7 |
| **Physical properties** | |
| **Phase** | solid |
| **Melting point** | 575 K (302 °C, 576 °F) |
| **Boiling point** | 610 K (337 °C, 639 °F) |
| **Density** near r.t. | ($At_2$) 6.35±0.15 g/cm$^3$ |

The bulk properties of astatine are not known with any certainty.[8] Research is limited by its short half-life, which prevents the creation of weighable quantities.[9] A visible piece of astatine would immediately vaporize itself because of the heat generated by its intense radioactivity.[10] It remains to be seen if, with sufficient cooling, a macroscopic quantity of astatine could be deposited as a thin film.[2] Astatine is usually classified as either a nonmetal or a metalloid;[11][12] metal formation has also been predicted.[2][13]

## Physical

Most of the physical properties of astatine have been estimated (by interpolation or extrapolation), using theoretically or empirically derived methods.[14] For example, halogens get darker with increasing atomic weight – fluorine is nearly colorless, chlorine is yellow-green, bromine is red-brown, and iodine is dark gray/violet. Astatine is sometimes described as probably being a black solid (assuming it follows this trend), or as having a metallic appearance (if it is a metalloid or a metal).[15][16][17] The melting and boiling points of astatine are also expected to follow the trend seen in the halogen series, increasing with atomic number. On this basis they are estimated to be 575 and 610 K (302 and 337 °C; 575 and 638 °F), respectively.[18] Some experimental evidence suggests astatine may have lower melting and boiling points than those implied by the halogen trend.[19] Astatine sublimes less readily than does iodine, having a lower vapor pressure.[9] Even so, half of a given quantity of astatine will vaporize in approximately an hour if put on a clean glass surface at room temperature.[a] The absorption spectrum of astatine in the middle ultraviolet region has lines at 224.401 and 216.225 nm, suggestive of 6p to 7s transitions.[21][22]

The structure of solid astatine is unknown.[23] As an analogue of iodine it may have an orthorhombic crystalline structure composed of diatomic astatine molecules, and be a semiconductor (with a band gap of 0.7 eV).[24] Alternatively, if condensed astatine forms a metallic phase, as has been predicted, it may have a monatomic face-centered cubic structure. Evidence for (or against) the existence of diatomic astatine ($At_2$) is sparse and inconclusive.[25][26][27][28][29] Some sources state that it does not exist, or at least has never been observed,[30][31] while other sources assert or imply

| | |
|---|---|
| | *(predicted)*[3] |
| **Molar volume** | ($At_2$) 32.94 $cm^3$/mol<br>*(predicted)*[3] |
| **Heat of vaporization** | ($At_2$) 54.39 kJ/mol[4] |

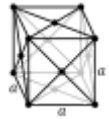
**Vapor pressure**

| **P** (Pa) | **1** | **10** | **100** | **1 k** | **10 k** | **100 k** |
|---|---|---|---|---|---|---|
| **at T** (K) | 361 | 392 | 429 | 475 | 531 | 607 |

**Atomic properties**

| | |
|---|---|
| **Oxidation states** | **−1**, **+1**, +3, +5, +7[5] |
| **Electronegativity** | Pauling scale: 2.2 |
| **Ionization energies** | 1st: 899.003 kJ/mol[6] |
| **Covalent radius** | 150 pm |
| **Van der Waals radius** | 202 pm |

**Miscellanea**

| | |
|---|---|
| **Crystal structure** | face-centered cubic (fcc)<br>*(predicted)*[2]  |
| **Thermal conductivity** | 1.7 W/(m·K) |
| **CAS Number** | 7440-68-8 |

**History**

| | |
|---|---|
| **Naming** | after Greek *astatos* (αστατος), meaning "unstable" |
| **Discovery** | Dale R. Corson, Kenneth Ross MacKenzie, Emilio Segrè (1940) |

its existence.[19][32][33] Despite this controversy, many properties of diatomic astatine have been predicted;[34] for example, its bond length would be 300 ±10 pm, dissociation energy 83.7 ±12.5 kJ·mol$^{-1}$,[35] and heat of vaporization ($\Delta H_{vap}$) 54.39 kJ·mol$^{-1}$.[4] The latter figure means that astatine may (at least) be metallic in the liquid state on the basis that elements with a heat of vaporization greater than ~42 kJ·mol$^{-1}$ are metallic when liquid;[36] diatomic iodine, with a value of 41.71 kJ·mol$^{-1}$,[37] falls just short of the threshold figure.[b]

**Most stable isotopes of astatine**

| iso | NA | half-life | DM | DE (MeV) | DP |
|---|---|---|---|---|---|
| **$^{209}$At** | syn | 5.41 h | β$^+$ | 3.486 | $^{209}$Po |
| | | | α | 5.758 | $^{205}$Bi |
| **$^{210}$At** | syn | 8.1 h | β$^+$ | 3.981 | $^{210}$Po |
| | | | α | 5.632 | $^{206}$Bi |
| **$^{211}$At** | syn | 7.21 h | ε | 0.786 | $^{211}$Po |
| | | | α | 5.983 | $^{207}$Bi |

## Chemical

The chemistry of astatine is "clouded by the extremely low concentrations at which astatine experiments have been conducted, and the possibility of reactions with impurities, walls and filters, or radioactivity by-products, and other unwanted nano-scale interactions."[24] Many of its apparent chemical properties have been observed using tracer studies on extremely dilute astatine solutions,[33][40] typically less than $10^{-10}$ mol·L$^{-1}$.[41] Some properties – such as anion formation – align with other halogens.[9] Astatine has some metallic characteristics as well, such as plating onto a cathode,[c] coprecipitating with metal sulfides in hydrochloric acid,[43] and forming a stable monatomic cation in aqueous solution.[43][44] It forms complexes with EDTA, a metal chelating agent,[45] and is capable of acting as a metal in antibody radiolabeling; in some respects astatine in the +1 state is akin to silver in the same state. Most of the organic chemistry of astatine is, however, analogous to that of iodine.[46]

Astatine has an electronegativity of 2.2 on the revised Pauling scale – lower than that of iodine (2.66) and the same as hydrogen. In hydrogen astatide (HAt) the negative charge is predicted to be on the hydrogen atom, implying that this compound should instead be referred to as astatine hydride.[47][48][49][50] That would be consistent with the electronegativity of astatine on the Allred–Rochow scale (1.9) being less than that of hydrogen (2.2).[51][d] The electron affinity of astatine is predicted to be reduced by one-third because of spin-orbit interactions.[41]

# Source

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