

Arsenic

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Arsenic is a chemical element with symbol **As** and atomic number 33. Arsenic occurs in many minerals, usually in combination with sulfur and metals, but also as a pure elemental crystal. Arsenic is a metalloid. It has various allotropes, but only the gray form is important to industry.

The primary use of metallic arsenic is in alloys of lead (for example, in car batteries and ammunition). Arsenic is a common n-type dopant in semiconductor electronic devices, and the optoelectronic compound gallium arsenide is the second most commonly used semiconductor after doped silicon. Arsenic and its compounds, especially the trioxide, are used in the production of pesticides, treated wood products, herbicides, and insecticides. These applications are declining, however.^[6]

A few species of bacteria are able to use arsenic compounds as respiratory metabolites. Trace quantities of arsenic are an essential dietary element in rats, hamsters, goats, chickens, and presumably many other species, including humans. However, arsenic poisoning occurs in multicellular life if quantities are larger than needed. Arsenic contamination of groundwater is a problem that affects millions of people across the world.

Characteristics

Physical characteristics

The three most common arsenic allotropes are metallic gray, yellow, and black arsenic, with gray being the most common.^[7] Gray arsenic (α -As, space group $R\bar{3}m$ No. 166) adopts a double-layered structure consisting of many interlocked, ruffled, six-membered rings. Because of weak bonding between the layers, gray arsenic is brittle and has a relatively low Mohs hardness of 3.5. Nearest and next-nearest neighbors form a distorted octahedral complex, with the three atoms in the same double-layer being slightly closer than the three atoms in the next.^[8] This relatively close packing leads to a high density of 5.73 g/cm³.^[9] Gray arsenic

Arsenic, $_{33}\text{As}$



General properties

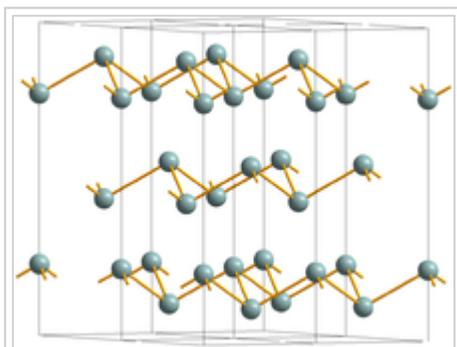
Name, symbol	arsenic, As
Allotropes	grey (most common), yellow, black
Appearance	metallic grey

Arsenic in the periodic table

Atomic number (<i>Z</i>)	33
Group, block	group 15 (pnictogens), p-block
Period	period 4
Element category	☐ metalloid
Standard atomic weight (\pm) (<i>A</i> _r)	74.921595(6) ^[1]
Electron configuration	[Ar] 3d ¹⁰ 4s ² 4p ³
per shell	2, 8, 18, 5

Physical properties

Phase	solid
Sublimation point	887 K (615 °C, 1137 °F)
Density	near r.t.



Crystal structure common to Sb, AsSb and gray As

is a semimetal, but becomes a semiconductor with a bandgap of 1.2–1.4 eV if amorphized.^[10] Gray arsenic is also the most stable form. Yellow arsenic is soft and waxy, and somewhat similar to tetraphosphorus (P₄). Both have four atoms arranged in a tetrahedral structure in which each atom is bound to each of the other three atoms by a single bond. This unstable allotrope, being molecular, is the most volatile, least dense, and most toxic. Solid yellow arsenic is produced by rapid cooling of arsenic vapor, As₄. It is rapidly transformed into gray arsenic by light. The yellow form has a density of 1.97 g/cm³.^[9] Black arsenic

is similar in structure to red phosphorus.^[9] Black arsenic can also be formed by cooling vapor at around 100–220 °C. It is glassy and brittle. It is also a poor electrical conductor.^[11]

Isotopes

Arsenic occurs in nature as a monoisotopic element, composed of one stable isotope, ⁷⁵As.^[12] As of 2003, at least 33 radioisotopes have also been synthesized, ranging in atomic mass from 60 to 92. The most stable of these is ⁷³As with a half-life of 80.30 days. All other isotopes have half-lives of under one day, with the exception of ⁷¹As (t_{1/2}=65.30 hours), ⁷²As (t_{1/2}=26.0 hours), ⁷⁴As (t_{1/2}=17.77 days), ⁷⁶As (t_{1/2}=1.0942 days), and ⁷⁷As (t_{1/2}=38.83 hours). Isotopes that are lighter than the stable ⁷⁵As tend to decay by β⁺ decay, and those that are heavier tend to decay by β[−] decay, with some exceptions.

At least 10 nuclear isomers have been described, ranging in atomic mass from 66 to 84. The most stable of arsenic's isomers is ^{68m}As with a half-life of 111 seconds.^[12]

Chemistry

	5.727 g/cm ³
when liquid, at m.p.	5.22 g/cm ³
Triple point	1090 K, 3628 kPa ^[2]
Critical point	1673 K, ? MPa
Heat of fusion	grey: 24.44 kJ/mol
Heat of vaporization	34.76 kJ/mol (?)
Molar heat capacity	24.64 J/(mol·K)

Vapor pressure

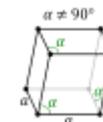
P (Pa)	1	10	100	1 k	10 k	100 k
at T (K)	553	596	646	706	781	874

Atomic properties

Oxidation states	5, 4, 3, 2, 1, ^[3] −1, −2, −3 (a mildly acidic oxide)
Electronegativity	Pauling scale: 2.18
Ionization energies	1st: 947.0 kJ/mol 2nd: 1798 kJ/mol 3rd: 2735 kJ/mol (more)
Atomic radius	empirical: 119 pm
Covalent radius	119±4 pm
Van der Waals radius	185 pm

Miscellanea

Crystal structure rhombohedral



Thermal expansion 5.6 μm/(m·K)^[4] (at r.t.)

Thermal conductivity 50.2 W/(m·K)

Arsenic has a similar electronegativity and ionization energies to its lighter congener phosphorus and as such readily forms covalent molecules with most of the nonmetals. Though stable in dry air, arsenic forms a golden-bronze tarnish upon exposure to humidity which eventually becomes a black surface layer.^[13] When heated in air, arsenic oxidizes to arsenic trioxide; the fumes from this reaction have an odor resembling garlic. This odor can be detected on striking arsenide minerals such as arsenopyrite with a hammer.^[2] It burns in oxygen to form arsenic trioxide and arsenic pentoxide, which have the same structure as the more well-known phosphorus compounds, and in fluorine to give arsenic pentafluoride.^[13] Arsenic (and some arsenic compounds) sublimes upon heating at atmospheric pressure, converting directly to a gaseous form without an intervening liquid state at 887 K (614 °C).^[2] The triple point is 3.63 MPa and 1,090 K (820 °C).^{[9][2]} Arsenic makes arsenic acid with concentrated nitric acid, arsenious acid with dilute nitric acid, and arsenic trioxide with concentrated sulfuric acid; however, it does not react with water, alkalis, or non-oxidising acids.^[14] Arsenic reacts with metals to form arsenides, though these are not ionic compounds containing the As^{3−} ion as the formation of such an anion would be highly endothermic and even the group 1 arsenides have properties of intermetallic compounds.^[13] Like germanium, selenium, and bromine, which like arsenic succeed the 3d transition series, arsenic is much less stable in the group oxidation state of +5 than its vertical neighbors phosphorus and antimony, and hence arsenic pentoxide and arsenic acid are potent oxidizers.^[13]

External links

- Wikipedia: Arsenic (<https://en.wikipedia.org/wiki/Arsenic>)

Electrical resistivity	333 nΩ·m (at 20 °C)				
Magnetic ordering	diamagnetic ^[5]				
Young's modulus	8 GPa				
Bulk modulus	22 GPa				
Mohs hardness	3.5				
Brinell hardness	1440 MPa				
CAS Number	7440-38-2				
	History				
Discovery	Early Bronze Age (2500 BC)				
First isolation	Albertus Magnus (1250)				
	Most stable isotopes of arsenic				
iso	NA	half-life	DM	DE (MeV)	DP
73As	syn	80.3 d	ε	–	⁷³ Ge
			γ	0.05D, 0.01D, e	–
74As	syn	17.78 d	ε	–	⁷⁴ Ge
			β ⁺	0.941	⁷⁴ Ge
			γ	0.595, 0.634	–
			β [−]	1.35, 0.717	⁷⁴ Se
75As	100%	is stable with 42 neutrons			