Silicon

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Silicon is a chemical element with symbol **Si** and atomic number 14. A hard and brittle crystalline solid with a blue-gray metallic luster, it is a tetravalent metalloid. It is a member of group 14 in the periodic table, along with carbon above it and germanium, tin, lead, and flerovium below. It is rather unreactive, though less so than germanium, and has great chemical affinity for oxygen; as such, it was first prepared and characterized in pure form only in 1823 by Jöns Jakob Berzelius.

Silicon is the eighth most common element in the universe by mass, but very rarely occurs as the pure element in the Earth's crust. It is most widely distributed in dusts, sands, planetoids, and planets as various forms of silicon dioxide (silica) or silicates. Over 90% of the Earth's crust is composed of silicate minerals, making silicon the second most abundant element in the Earth's crust (about 28% by mass) after oxygen.[9]

Most silicon is used commercially without being separated, and often with little processing of the natural minerals. Such use includes industrial construction with clays, silica sand, and stone. Silicate is used in Portland cement for mortar and stucco, and mixed with silica sand and gravel to make concrete for walkways, foundations, and roads. Silicates are used in whiteware ceramics such as porcelain, and in traditional quartz-based soda-lime glass and many other specialty glasses. Silicon compounds such as silicon carbide are used as abrasives and components of high-strength ceramics.

Elemental silicon also has a large impact on the modern world economy. Most free silicon is used in the steel refining, aluminium-casting, and fine chemical industries (often to make fumed silica). Even more visibly, the relatively small portion of very highly purified silicon used in semiconductor electronics (< 10%) is essential to integrated circuits — most computers, cell phones, and modern technology depend on it. Silicon is the basis of the widely used synthetic polymers called silicones.

Silicon, $_{14}$Si

Spectral lines of silicon

General properties

Name, symbol	silicon, Si
Appearance	crystalline, reflective with bluish-tinged faces

Silicon in the periodic table

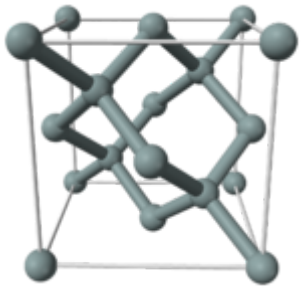
Atomic number (Z)	14
Group, block	group 14 (carbon group), p-block
Period	period 3
Element category	metalloid
Standard atomic weight (A_r)	28.085[1] (28.084–28.086)[2]
Electron configuration	[Ne] $3s^2$ $3p^2$
per shell	2, 8, 4

Physical properties

Silicon is an essential element in biology, although only tiny traces are required by animals.[10] However, various sea sponges and microorganisms, such as diatoms and radiolaria, secrete skeletal structures made of silica. Silica is deposited in many plant tissues, such as in the bark and wood of *Chrysobalanaceae* and the silica cells and silicified trichomes of *Cannabis sativa*, horsetails and many grasses.[11]

Characteristics

Physical



Silicon crystallizes in a diamond cubic crystal structure

Silicon is a solid at room temperature, with a melting point of 1,414 °C (2,577 °F) and a boiling point of 3,265 °C (5,909 °F). Like water, it has a greater density in a liquid state than in a solid state and it expands when it freezes, unlike most other substances. With a relatively high thermal conductivity of 149 $W \cdot m^{-1} \cdot K^{-1}$, silicon conducts heat well.

In its crystalline form, pure silicon has a gray color and a metallic luster. Like germanium, silicon is rather strong, very brittle, and prone to chipping. Silicon, like carbon and germanium, crystallizes in a diamond cubic crystal structure with a lattice spacing of 0.5430710 nm (5.430710 Å).[12]

The outer electron orbital of silicon, like that of carbon, has four valence electrons. The 1*s*, 2*s*, 2*p* and 3*s* subshells are completely filled while the 3*p* subshell contains two electrons out of a possible six.

Silicon is a semiconductor. It has a negative temperature coefficient of resistance, since the number of free charge carriers increases with temperature. The electrical resistance of single crystal silicon significantly changes under the

Phase	solid
Melting point	1687 K (1414 °C, 2577 °F)
Boiling point	3538 K (3265 °C, 5909 °F)
Density near r.t.	2.3290 g/cm^3
when liquid, at m.p.	2.57 g/cm^3
Heat of fusion	50.21 kJ/mol
Heat of vaporization	383 kJ/mol
Molar heat capacity	19.789 J/(mol·K)

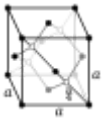
Vapor pressure

P (Pa)	**1**	**10**	**100**	**1 k**	**10 k**	**100 k**
at T (K)	1908	2102	2339	2636	3021	3537

Atomic properties

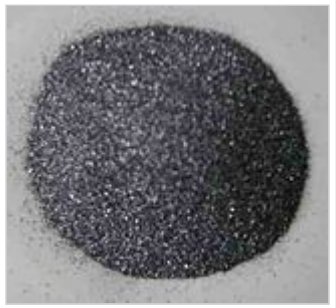
Oxidation states	**4**, 3, 2, 1[3] −1, −2, −3, **−4** (an amphoteric oxide)
Electronegativity	Pauling scale: 1.90
Ionization energies	1st: 786.5 kJ/mol 2nd: 1577.1 kJ/mol 3rd: 3231.6 kJ/mol (more)
Atomic radius	empirical: 111 pm
Covalent radius	111 pm
Van der Waals radius	210 pm

Miscellanea

Crystal structure	face-centered diamond-cubic 
Speed of sound thin rod	8433 m/s (at 20 °C)

application of mechanical stress due to the piezoresistive effect.[13] Heavily boron-doped silicon is a type II superconductor with a transition temperature T_c of 0.4 K.[14]

Chemical


Silicon powder

Silicon is a metalloid, readily donating or sharing its four outer electrons, and it typically forms four bonds. Like carbon, its four bonding electrons enable it to combine with many other elements or compounds to form a wide range of compounds. Unlike carbon, it can accept additional electrons and form five or six bonds in a sometimes more labile silicate form. Tetra-valent silicon is relatively inert; it reacts with halogens and dilute alkalis, but most acids (except some hyper-reactive combinations of nitric acid and hydrofluoric acid) have no effect on it.

Isotopes

Naturally occurring silicon is composed of three stable isotopes, ^{28}Si (92.23%), ^{29}Si (4.67%), and ^{30}Si (3.10%), with ^{28}Si being the most abundant.[15] Out of these, only ^{29}Si is of use in NMR and EPR spectroscopy,[16] as it is the only one with a nuclear spin ($I = \frac{1}{2}$).[17]

Twenty radioisotopes have been characterized, with the most stable being ^{32}Si with a half-life of 170 years, and ^{31}Si with a half-life of 157.3 minutes.[15] All of the remaining radioactive isotopes have half-lives that are less than seven seconds, and the majority of these have half-lives that are less than one tenth of a second.[15] Silicon does not have any known nuclear isomers.[15] ^{32}Si undergoes low-energy beta decay to ^{32}P and then stable ^{32}S. ^{31}Si may be produced by the neutron activation of natural silicon and is thus useful for quantitative analysis.[17]

Thermal expansion	2.6 µm/(m·K) (at 25 °C)
Thermal conductivity	149 W/(m·K)
Electrical resistivity	2.3×10^3 Ω·m (at 20 °C)[4]
Band gap	1.12 eV (at 300 K)
Magnetic ordering	diamagnetic[5]
Young's modulus	130–188 GPa[6]
Shear modulus	51–80 GPa[6]
Bulk modulus	97.6 GPa[6]
Poisson ratio	0.064–0.28[6]
Mohs hardness	7
CAS Number	7440-21-3
	History
Naming	after Latin 'silex' or 'silicis', meaning flint
Prediction	Antoine Lavoisier (1787)
Discovery and first isolation	Jöns Jacob Berzelius[7][8] (1823)
Named by	Thomas Thomson (1817)

Most stable isotopes of silicon

iso	NA	half-life	DM	DE (MeV)	DP
^{28}Si	92.2%	is stable with 14 neutrons			
^{29}Si	4.7%	is stable with 15 neutrons			
^{30}Si	3.1%	is stable with 16 neutrons			
^{31}Si	trace	2.62 h	β−	1.495	^{31}P
^{32}Si	trace	153 y	β−	13.020	^{32}P

The isotopes of silicon range in mass number from 22 to 44.[15] The most common decay mode of the isotopes with mass numbers lower than the three stable isotopes is inverse beta decay, primarily forming aluminium isotopes (13 protons) as decay products.[15] The most common decay mode for the heavier unstable isotopes is beta decay, primarily forming phosphorus isotopes (15 protons) as decay products.[15]

External links

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