

Seaborgium

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Seaborgium is a chemical element with symbol **Sg** and atomic number 106. It is named after the American nuclear chemist Glenn T. Seaborg. It is one of only two elements named after a living person at the time of naming, the other being oganesson. It is a synthetic element (an element that can be created in a laboratory but is not found in nature) and radioactive; the most stable known isotope, ²⁶⁹Sg, has a half-life of approximately 3.1 minutes.

In the periodic table of the elements, it is a d-block transactinide element. It is a member of the 7th period and belongs to the group 6 elements as the fourth member of the 6d series of transition metals. Chemistry experiments have confirmed that seaborgium behaves as the heavier homologue to tungsten in group 6. The chemical properties of seaborgium are characterized only partly, but they compare well with the chemistry of the other group 6 elements.

In 1974, a few atoms of seaborgium were produced in laboratories in the former Soviet Union and in the United States. The priority of the discovery and therefore the naming of the element was disputed between Soviet and American scientists, and it was not until 1997 that International Union of Pure and Applied Chemistry (IUPAC) established seaborgium as the official name for the element.

Isotopes

Super-heavy elements such as seaborgium are produced by bombarding lighter elements in particle accelerators that induces fusion reactions. Whereas most of the isotopes of seaborgium can be synthesized directly this way, some heavier ones have only been observed as decay products of elements with higher atomic numbers.^[11]

Depending on the energies involved, the former are separated into "hot" and "cold". In hot fusion reactions, very light, high-energy projectiles are accelerated toward very heavy targets (actinides), giving rise to compound nuclei at high excitation energy (~40–50 MeV) that may either fission or evaporate several (3 to 5) neutrons.^[11] In cold fusion reactions, the produced fused nuclei have a relatively low

Seaborgium, 106Sg

General properties

Name, symbol seaborgium, Sg

Seaborgium in the periodic table

Atomic number (*Z*) 106

Group, block group 6, d-block

Period period 7

Element category ☐ transition metal

Standard atomic weight (*A*_r) [269]

Electron configuration [Rn] 5f¹⁴ 6d⁴ 7s² ^[1]
per shell 2, 8, 18, 32, 32, 12, 2

Physical properties

Phase solid (*predicted*)^[2]

Density near r.t. 35.0 g/cm³
(*predicted*)^{[1][3]}

Atomic properties

Oxidation states **6**, (5), (**4**), (3), 0^{[1][3]}
(parenthesized oxidation states are predictions)

Ionization energies
1st: 752.6 kJ/mol
2nd: 1732.9 kJ/mol
3rd: 2483.5 kJ/mol

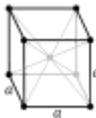
excitation energy (~10–20 MeV), which decreases the probability that these products will undergo fission reactions. As the fused nuclei cool to the ground state, they require emission of only one or two neutrons, and thus, allows for the generation of more neutron-rich products.^[12] The latter is a distinct concept from that of where nuclear fusion claimed to be achieved at room temperature conditions (see cold fusion).^[13]

Seaborgium has no stable or naturally occurring isotopes. Several radioactive isotopes have been synthesized in the laboratory, either by fusing two atoms or by observing the decay of heavier elements. Twelve different isotopes of seaborgium have been reported with atomic masses 258–267, 269, and 271, three of which, seaborgium-261, 263, and 265, have known metastable states. All of these decay only through alpha decay and spontaneous fission, with the single exception of seaborgium-261 that can also undergo electron capture to dubnium-261.^[9]

There is a trend toward increasing half-lives for the heavier isotopes; thus the heaviest three known isotopes, ²⁶⁷Sg, ²⁶⁹Sg, and ²⁷¹Sg, are also the longest-lived, having half-lives in minutes. Some other isotopes in this region are predicted to have comparable or even longer half-lives, with the longest-lived predicted isotope being ²⁷²Sg which is expected to have a half-life of about an hour. Additionally, ²⁶³Sg, ²⁶⁵Sg, ^{265m}Sg, as well as the predicted ²⁶⁸Sg have or should have half-lives measured in seconds. All the remaining isotopes have half-lives measured in milliseconds, with the exception of the shortest-lived isotope, ^{261m}Sg, with a half-life of only 92 microseconds.^[9]

The proton-rich isotopes from ²⁵⁸Sg to ²⁶¹Sg were directly produced by cold fusion; all heavier isotopes were produced from the repeated alpha decay of the heavier elements hassium, darmstadtium, and flerovium, with the exceptions of the isotopes ^{263m}Sg, ²⁶⁴Sg, ²⁶⁵Sg, and ^{265m}Sg, which were directly produced by hot fusion through irradiation of actinide targets. The twelve isotopes of seaborgium have half-lives ranging from 92 microseconds for ²⁶¹Sg to 3.1 minutes for ²⁶⁹Sg.^[9]

Properties

	(more) <i>(all but first estimated)</i> ^[1]
Atomic radius	empirical: 132 pm <i>(predicted)</i> ^[1]
Covalent radius	143 pm <i>(estimated)</i> ^[4]
Miscellanea	
Crystal structure	body-centered cubic (bcc) <i>(predicted)</i> ^[2]
	
CAS Number	54038-81-2
History	
Naming	after Glenn T. Seaborg
Discovery	Lawrence Berkeley National Laboratory (1974)
Most stable isotopes of seaborgium	

Physical

Seaborgium is expected to be a solid under normal conditions and assume a body-centered cubic crystal structure, similar to its lighter congener tungsten.^[2] It should be a very heavy metal with a density of around 35.0 g/cm³, which would be the fourth-highest of any of the 118 known elements, lower than only bohrium (37.1 g/cm³), meitnerium (37.4 g/cm³) and hassium (41 g/cm³), the three following elements in the periodic table.^[1] In comparison, the densest known element that has had its density measured, osmium, has a density of only 22.61 g/cm³. This results from seaborgium's high atomic weight, the lanthanide and actinide contractions, and relativistic effects, although production of enough seaborgium to measure this quantity would be impractical, and the sample would quickly decay.^[1]

Chemical

Seaborgium is the fourth member of the 6d series of transition metals and the heaviest member of group 6 in the periodic table, below chromium, molybdenum, and tungsten. All the members of the group form a diversity of oxoanions. They readily portray their group oxidation state of +6, although this is highly oxidising in the case of chromium, and this state becomes more and more stable to reduction as the group is descended: indeed, tungsten is the last of the 5d transition metals where all four 5d electrons participate in metallic bonding.^[14] As such, seaborgium should have +6 as its most stable oxidation state, both in the gas phase and in aqueous solution, and this is the only oxidation state that is experimentally known for it; the +5 and +4 states should be less stable and the +3 state, the most common for chromium, would be the least stable for seaborgium.^[1] Experimental chemical investigation has been hampered due to the need to produce seaborgium one atom at a time, its short half-life, and the resulting necessary harshness of the experimental conditions.^[15]

This stabilisation of the highest oxidation state occurs in the early 6d elements because of the similarity between the energies of the 6d and 7s orbitals, since the 7s orbitals are relativistically stabilised and the 6d orbitals are relativistically destabilised. This effect is so large in the seventh period that seaborgium is expected to lose 6d electrons before 7s electrons (Sg, [Rn]5f¹⁴6d⁴7s²; Sg⁺, [Rn]5f¹⁴6d³7s²; Sg²⁺, [Rn]5f¹⁴6d³7s¹; Sg⁴⁺, [Rn]5f¹⁴6d²; Sg⁶⁺, [Rn]5f¹⁴). Because of the great destabilisation of the 7s orbital, Sg⁴⁺ should be even more unstable than W⁴⁺ and should be very readily oxidised to Sg⁶⁺. The predicted ionic radius of

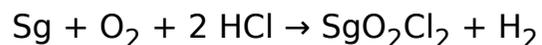
iso	NA	half-life	DM	DE (MeV)	DP
271Sg	syn	1.9 min	67% α	8.54	267Rf
			33% SF		
269Sg	syn	3.1 ^{+3.7} _{-1.1} min	α	8.50(6)	265Rf
267Sg	syn	1.4 min	17% α	8.20	263Rf
			83% SF		
265mSg	syn	16.2 s	α	8.70	261mRf
265Sg	syn	8.9 s	α	8.90, 8.84, 8.76	261Rf

the hexacoordinate Sg⁶⁺ ion is 65 pm, while the predicted atomic radius of seaborgium is 128 pm. Nevertheless, the stability of the highest oxidation state is still expected to decrease as Lr³⁺ > Rf⁴⁺ > Db⁵⁺ > Sg⁶⁺. Some predicted standard reduction potentials for seaborgium ions in aqueous acidic solution are as follows:^[1]

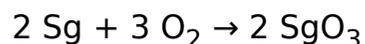


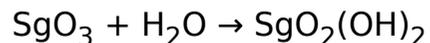
Seaborgium should form a very volatile hexafluoride (SgF₆) as well as a moderately volatile hexachloride (SgCl₆), pentachloride (SgCl₅), and oxychlorides SgO₂Cl₂ and SgOCl₄.^[3] SgO₂Cl₂ is expected to be the most stable of the seaborgium oxychlorides and to be the least volatile of the group 6 oxychlorides, with the sequence MoO₂Cl₂ > WO₂Cl₂ > SgO₂Cl₂.^[1]

The volatile seaborgium(VI) compounds SgCl₆ and SgOCl₄ are expected to be unstable to decomposition to seaborgium(V) compounds at high temperatures, analogous to MoCl₆ and MoOCl₄; this should not happen for SgO₂Cl₂ due to the much higher energy gap between the highest occupied and lowest unoccupied molecular orbitals, despite the similar Sg-Cl bond strengths (similarly to molybdenum and tungsten).^[16] Thus, in the first experimental chemical studies of seaborgium in 1995 and 1996, seaborgium atoms were produced in the reaction ²⁴⁸Cm(²²Ne,4n)²⁶⁶Sg, thermalised, and reacted with an O₂/HCl mixture. The adsorption properties of the resulting oxychloride were measured and compared with those of molybdenum and tungsten compounds. The results indicated that seaborgium formed a volatile oxychloride akin to those of the other group 6 elements, and confirmed the decreasing trend of oxychloride volatility down group 6:



In 2001, a team continued the study of the gas phase chemistry of seaborgium by reacting the element with O₂ in a H₂O environment. In a manner similar to the formation of the oxychloride, the results of the experiment indicated the formation of seaborgium oxide hydroxide, a reaction well known among the lighter group 6 homologues as well as the pseudohomologue uranium.^[17]





Molybdenum and tungsten are very similar to each other and show important differences to the smaller chromium, and seaborgium is expected to follow the chemistry of tungsten and molybdenum quite closely, forming an even greater variety of oxoanions, the simplest among them being seaborgate, SgO_4^{2-} , which would form from the rapid hydrolysis of $\text{Sg}(\text{H}_2\text{O})_6^{6+}$, although this would take place less readily than with molybdenum and tungsten as expected from seaborgium's greater size. Seaborgium should hydrolyse less readily than tungsten in hydrofluoric acid at low concentrations, but more readily at high concentrations, also forming complexes such as SgO_3F^- and SgOF_5^- : complex formation competes with hydrolysis in hydrofluoric acid.^[1] These predictions have largely been confirmed. In experiments conducted in 1997 and 1998, seaborgium was eluted from cation-exchange resin using a HNO_3/HF solution, most likely as neutral SgO_2F_2 or the anionic complex ion $[\text{SgO}_2\text{F}_3]^-$ rather than SgO_4^{2-} . In contrast, in 0.1 M nitric acid, seaborgium does not elute, unlike molybdenum and tungsten, indicating that the hydrolysis of $[\text{Sg}(\text{H}_2\text{O})_6]^{6+}$ only proceeds as far as the cationic complex $[\text{Sg}(\text{OH})_4(\text{H}_2\text{O})]^{2+}$ or $[\text{Sg}(\text{OH})_3(\text{H}_2\text{O})_2]^+$, while that of molybdenum and tungsten proceeds to neutral $[\text{MO}_2(\text{OH})_2]$.^[1]

The only other oxidation state known for seaborgium other than the group oxidation state of +6 is the zero oxidation state. Similarly to its three lighter congeners, forming chromium hexacarbonyl, molybdenum hexacarbonyl, and tungsten hexacarbonyl, seaborgium has been shown in 2014 to also form seaborgium hexacarbonyl, $\text{Sg}(\text{CO})_6$. Like its molybdenum and tungsten homologues, seaborgium hexacarbonyl is a volatile compound that reacts readily with silicon dioxide.^[15]

Source

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