

Darmstadtium

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Darmstadtium is a chemical element with symbol **Ds** and atomic number 110. It is an extremely radioactive synthetic element. The most stable known isotope, darmstadtium-281, has a half-life of approximately 10 seconds.^[6] Darmstadtium was first created in 1994 by the GSI Helmholtz Centre for Heavy Ion Research near the city of Darmstadt, Germany, after which it was named.

In the periodic table, it is a d-block transactinide element. It is a member of the 7th period and is placed in the group 10 elements, although no chemical experiments have yet been carried out to confirm that it behaves as the heavier homologue to platinum in group 10 as the eighth member of the 6d series of transition metals. Darmstadtium is calculated to have similar properties to its lighter homologues, nickel, palladium, and platinum.

Isotopes

For a detailed list of information on the discovery of each individual darmstadtium isotope, see isotopes of darmstadtium.

Darmstadtium 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. Nine different isotopes of darmstadtium have been reported with atomic masses 267, 269–271, 273, 277, and 279–281, although darmstadtium-267 and darmstadtium-280 are unconfirmed. Two darmstadtium isotopes, darmstadtium-270 and darmstadtium-271, have known metastable states. Most of these decay predominantly through alpha decay, but some undergo spontaneous fission.^[17]

Stability and half-lives

All darmstadtium isotopes are extremely unstable and radioactive; in general, the heavier isotopes are more stable than the lighter. The most stable known darmstadtium isotope, ²⁸¹Ds, is also the heaviest known darmstadtium isotope; it has

Darmstadtium, ¹¹⁰Ds

General properties	
Name, symbol	darmstadtium, Ds
Darmstadtium in the periodic table	
Atomic number (<i>Z</i>)	110
Group, block	group 10, d-block
Period	period 7
Element category	unknown, but probably a transition metal
Standard atomic weight (<i>A</i> _r)	[281]
Electron configuration	[Rn] 5f ¹⁴ 6d ⁸ 7s ² (predicted) ^[2]
per shell	2, 8, 18, 32, 32, 16, 2 (predicted) ^[2]
Physical properties	
Phase	solid (predicted) ^[3]
Density near r.t.	34.8 g/cm ³ (predicted) ^[2]
Atomic properties	
Oxidation states	8, 6, 4, 2, 0 (predicted) ^{[2][4]}
Ionization energies	1st: 955.2 kJ/mol 2nd: 1891.1 kJ/mol 3rd: 3029.6 kJ/mol

a half-life of 11 seconds. The isotope ²⁷⁹Ds has a half-life of 0.18 seconds respectively. The remaining six isotopes and two metastable states have half-lives between 1 microsecond and 70 milliseconds.^[17] Some unknown isotopes in this region, such as ²⁷²Ds and ²⁷⁴⁻²⁷⁶Ds, are predicted to also have rather long half-lives of a few seconds.^{[17][18]} Before its discovery, ²⁷⁷Ds was predicted to have a half-life of around 5 seconds, but it has since been found to have a half-life of only 5.7 milliseconds.^[17] Likewise, while ²⁸⁰Ds was originally predicted to have a half-life of about 11 seconds, more recent work that may have detected it as the electron-capture daughter of ²⁸⁰Rg, have found for it a half-life of much less than a second.^[19]

The undiscovered isotope ²⁸⁴Ds has been predicted to be the most stable towards beta decay;^[26] however, no known darmstadtium isotope has been observed to undergo beta decay.^[17] Theoretical calculation in a quantum tunneling model reproduces the experimental alpha decay half-life data for the known darmstadtium isotopes.^{[27][28]} It also predicts that the undiscovered isotope ²⁹⁴Ds, which has a magic number of neutrons (184),^[2] would have an alpha decay half-life on the order of 311 years: exactly the same approach predicts a ~3500-year alpha half-life for the non-magic ²⁹³Ds isotope, however.^{[29][30]}

Predicted properties

Chemical

Darmstadtium is the eighth member of the 6d series of transition metals. Since copernicium (element 112) has been shown to be a transition metal, it is expected that all the elements from 104 to 112 would form a fourth transition metal series, with darmstadtium as part of the platinum group metals^[15] and a noble metal.^[2] Calculations on its ionization potentials and atomic and ionic radii are similar to that of its lighter homologue platinum, thus implying that darmstadtium's basic properties will resemble those of the other group 10 elements, nickel, palladium, and platinum.^[2]

(more) (all estimated)^[2]

Atomic radius

empirical: 132 pm (predicted)^{[2][4]}

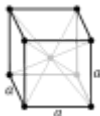
Covalent radius

128 pm (estimated)^[5]

Miscellanea

Crystal structure

body-centered cubic (bcc) (predicted)^[3]



CAS Number

54083-77-1

History

Naming

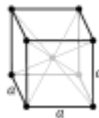
after Darmstadt, Germany, where it was discovered

Discovery

Gesellschaft für Schwerionenforschung (1994)

Most stable isotopes of darmstadtium

iso	NA	half-life	DM	DE (MeV)	DP
²⁸¹ Ds	syn	11 s	94% SF		
			6% α	8.67	²⁷⁷ Hs
²⁷⁹ Ds	syn	0.20 s	10% α	9.70	²⁷⁵ Hs
			90% SF		



Prediction of the probable chemical properties of darmstadtium has not received much attention recently. Darmstadtium is expected to be a noble metal. Based on the most stable oxidation states of the lighter group 10 elements, the most stable oxidation states of darmstadtium are predicted to be the +6, +4, and +2 states; however, the neutral state is predicted to be the most stable in aqueous solutions. In comparison, only palladium and platinum are known to show the maximum oxidation state in the group, +6, while the most stable states are +4 and +2 for both nickel and palladium. It is further expected that the maximum oxidation states of elements from bohrium (element 107) to darmstadtium (element 110) may be stable in the gas phase but not in aqueous solution.^[2] Darmstadtium hexafluoride (DsF₆) is predicted to have very similar properties to its lighter homologue platinum hexafluoride (PtF₆), having very similar electronic structures and ionization potentials.^{[2][31][32]} It is also expected to have the same octahedral molecular geometry as PtF₆.^[33] Other predicted darmstadtium compounds are darmstadtium carbide (DsC) and darmstadtium tetrachloride (DsCl₄), both of which are expected to behave like their lighter homologues.^[33]

Physical and atomic

Darmstadtium is expected to be a solid under normal conditions and to crystallize in the body-centered cubic structure, unlike its lighter congeners which crystallize in the face-centered cubic structure, because it is expected to have different electron charge densities from them.^[3] It should be a very heavy metal with a density of around 34.8 g/cm³. In comparison, the densest known element that has had its density measured, osmium, has a density of only 22.61 g/cm³.^[2] This results from darmstadtium's high atomic weight, the lanthanide and actinide contractions, and relativistic effects, although production of enough darmstadtium to measure this quantity would be impractical, and the sample would quickly decay.^[2]

The outer electron configuration of darmstadtium is calculated to be 6d⁸7s², which obeys the Aufbau principle and does not follow platinum's outer electron configuration of 5d⁹6s¹. This is due to the relativistic stabilization of the 7s² electron pair over the whole seventh period, so that none of the elements from 104 to 112 are expected to have electron configurations violating the Aufbau principle. The atomic radius of darmstadtium is expected to be around 132 pm.^[2]

Experimental chemistry

Unambiguous determination of the chemical characteristics of darmstadtium has yet to have been established^[34] due to the short half-lives of darmstadtium isotopes and a limited number of likely volatile compounds that could be studied on a very small scale. One of the few darmstadtium compounds that are likely to be sufficiently volatile is darmstadtium hexafluoride (DsF₆), as its lighter homologue platinum hexafluoride (PtF₆) is volatile above 60 °C and therefore the analogous compound of darmstadtium might also be sufficiently volatile;^[15] a volatile octafluoride (DsF₈) might also be possible.^[2] For chemical studies

to be carried out on a transactinide, at least four atoms must be produced, the half-life of the isotope used must be at least 1 second, and the rate of production must be at least one atom per week.^[15] Even though the half-life of ²⁸¹Ds, the most stable confirmed darmstadtium isotope, is 11 seconds, long enough to perform chemical studies, another obstacle is the need to increase the rate of production of darmstadtium isotopes and allow experiments to carry on for weeks or months so that statistically significant results can be obtained. Separation and detection must be carried out continuously to separate out the darmstadtium isotopes and automated systems can then experiment on the gas-phase and solution chemistry of darmstadtium as the yields for heavier elements are predicted to be smaller than those for lighter elements; some of the separation techniques used for bohrium and hassium could be reused. However, the experimental chemistry of darmstadtium has not received as much attention as that of the heavier elements from copernicium to livermorium.^{[2][34][35]}

The more neutron-rich darmstadtium isotopes are the most stable^[17] and are thus more promising for chemical studies;^{[2][15]} however, they can only be produced indirectly from the alpha decay of heavier elements,^{[6][24][25]} and indirect synthesis methods are not favourable for chemical studies.^[2] The more neutron-rich isotopes ²⁷⁶Ds and ²⁷⁷Ds might be produced directly in the reaction between thorium-232 and calcium-48, but the yield is expected to be low.^{[2][36][37]} Furthermore, this reaction has already been tested without success,^[36] and more recent experiments that have successfully synthesized ²⁷⁷Ds using indirect methods show that it has a short half-life of 5.7 ms, not long enough to perform chemical studies.^[24]

Source

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