Nobelium

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Nobelium is a synthetic chemical element with symbol **No** and atomic number 102. It is named in honor of Alfred Nobel, the inventor of dynamite and benefactor of science. A radioactive metal, it is the tenth transuranic element and is the penultimate member of the actinide series. Like all elements with atomic number over 100, nobelium can only be produced in particle accelerators by bombarding lighter elements with charged particles. A total of twelve nobelium isotopes are known to exist; the most stable is ^{259}No with a half-life of 58 minutes, but the shorter-lived ^{255}No (half-life 3.1 minutes) is most commonly used in chemistry because it can be produced on a larger scale.

Chemistry experiments have confirmed that nobelium behaves as a heavier homolog to ytterbium in the periodic table. The chemical properties of nobelium are not completely known: they are mostly only known in aqueous solution. Before nobelium's discovery, it was predicted that it would show a stable +2 oxidation state as well as the +3 state characteristic of the other actinides: these predictions were later confirmed, as the +2 state is much more stable than the +3 state in aqueous solution and it is difficult to keep nobelium in the +3 state.

In the 1950s and 1960s, many claims of the discovery of nobelium were made from laboratories in Sweden, the Soviet Union, and the United States. Although the Swedish scientists soon retracted their claims, 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) credited the Soviet team with the discovery, but retained nobelium, the Swedish proposal, as the name of the element due to its long-standing use in the literature.

Characteristics

Physical

In the periodic table, nobelium is located to the right of the actinide mendelevium, to the left of the actinide lawrencium, and below the lanthanide ytterbium. Nobelium metal has not yet been prepared in bulk quantities, and bulk preparation is currently

Nobelium, $_{102}$No	
General properties	
Name, symbol	nobelium, No
Nobelium in the periodic table	
Atomic number (Z)	102
Group, block	group n/a, f-block
Period	period 7
Element category	☐ actinide
Standard atomic weight (A_r)	[259]
Electron configuration	[Rn] 5f^{14} 7s^2
per shell	2, 8, 18, 32, 32, 8, 2
Physical properties	
Phase	solid *(predicted)*[1]
Melting point	1100 K (827 °C, 1521 °F) *(predicted)*[1]
Density near r.t.	9.9(4) g/cm^3 *(predicted)*[2]
Atomic properties	
Oxidation states	**2**, 3
Electronegativity	Pauling scale: 1.3 *(predicted)*[3]
Ionization energies	1st: 641.6 kJ/mol 2nd: 1254.3 kJ/mol

impossible.[13] Nevertheless, a number of predictions and some preliminary experimental results have been done regarding its properties.[13]

The lanthanides and actinides, in the metallic state, can exist as either divalent (such as europium and ytterbium) or trivalent (most other lanthanides) metals. The former have $f^{n+1}s^2$ configurations, whereas the latter have $f^{n}d^1s^2$ configurations. In 1975, Johansson and Rosengren examined the measured and predicted values for the cohesive energies (enthalpies of crystallization) of the metallic lanthanides and actinides, both as divalent and trivalent metals.[14][15] The conclusion was that the increased binding energy of the $[Rn]5f^{13}6d^17s^2$ configuration over the $[Rn]5f^{14}7s^2$ configuration for nobelium was not enough to compensate for the energy needed to promote one 5f electron to 6d, as is true also for the very late actinides: thus einsteinium, fermium, mendelevium, and nobelium were expected to be divalent metals, although for nobelium this prediction has not yet been confirmed.[14] The increasing predominance of the divalent state well before the actinide series concludes is attributed to the relativistic stabilization of the 5f electrons, which increases with increasing atomic number: an effect of this is that nobelium is predominantly divalent instead of trivalent, unlike all the other lanthanides and actinides.[16] In 1986, nobelium metal was estimated to have an enthalpy of sublimation between 126 kJ·mol^{-1}, a value close to the values for einsteinium, fermium, and mendelevium and supporting the theory that nobelium would form a divalent metal.[13] Like the other divalent late actinides (except the once again trivalent lawrencium), metallic nobelium should assume a face-centered cubic crystal structure.[2] Divalent nobelium metal should have a metallic radius of around 197 pm.[13] Nobelium's melting point has been predicted to be 827 °C, the same value as that estimated for the neighboring element mendelevium.[17] Its density is predicted to be around 9.9 ± 0.4 g·cm^{-3}.[2]

Chemical

The chemistry of nobelium is incompletely characterized and is known only in aqueous solution, in which it can take on the +3 or +2 oxidation states, the latter being more stable.[5] It was largely expected before the discovery of nobelium that in solution, it would behave like the other actinides, with the trivalent state being predominant; however, Seaborg predicted in 1949 that the +2 state would also be relatively stable

3rd: 2605.1 kJ/mol
(all estimated)

Miscellanea

Crystal structure	face-centered cubic (fcc)
	(predicted)[2]
CAS Number	10028-14-5

History

Naming	after Alfred Nobel
Discovery	Joint Institute for Nuclear Research (1966)

Most stable isotopes of nobelium

for nobelium, as the No^{2+} ion would have the ground-state electron configuration [Rn]$5f^{14}$, including the stable filled $5f^{14}$ shell. It took nineteen years before this prediction was confirmed.[18]

In 1967, experiments were conducted to compare nobelium's chemical behavior to that of terbium, californium, and fermium. All four elements were reacted with chlorine and the resulting chlorides were deposited along a tube, along which they were carried by a gas. It was found that the nobelium chloride produced was strongly adsorbed on solid surfaces, proving that it was not very volatile, like the chlorides of the other three investigated elements. However, both $NoCl_2$ and $NoCl_3$ were expected to exhibit nonvolatile behavior and hence this experiment was inconclusive as to what the preferred oxidation state of nobelium was.[18] Determination of nobelium's favoring of the +2 state had to wait until the next year, when cation-exchange chromatography and coprecipitation experiments were carried out on around fifty thousand ^{255}No atoms, finding that it behaved differently from the other actinides and more like the divalent alkaline earth metals. This proved that in aqueous solution, nobelium is most stable in the divalent state when strong oxidizers are absent.[18] Later experimentation in 1974 showed that nobelium eluted with the alkaline earth metals, between Ca^{2+} and Sr^{2+}.[18] Nobelium is the only f-block element for which the +2 state is the most common and stable one in aqueous solution. This occurs because of the large energy gap between the 5f and 6d orbitals at the end of the actinide series.[19]

Nobelium's complexing ability with chloride ions is most similar to that of barium, which complexes rather weakly.[18] Its complexing ability with citrate, oxalate, and acetate in an aqueous solution of 0.5 M ammonium nitrate is between that of calcium and strontium, although it is somewhat closer to that of strontium.[18]

iso	NA	half-life	DM	DE (MeV)	DP
^{253}No	syn	1.62 min	80% α	8.14, 8.06, 8.04, 8.01	^{249}Fm
			20% β+		^{253}Md
^{254}No	syn	51 s	90% α		^{250}Fm
			10% β+		^{254}Md
^{255}No	syn	3.1 min	61% α	8.12, 8.08, 7.93	^{251}Fm
			39% β+	2.012	^{255}Md
^{257}No	syn	25 s	99% α	8.32, 8.22	^{253}Fm
			1% β+		^{257}Md
^{259}No	syn	58 min	75% α	7.69, 7.61, 7.53....	^{255}Fm
			25% ε		^{259}Md
			10% SF		

The standard reduction potential of the $E°(No^{3+}{\to}No^{2+})$ couple was estimated in 1967 to be between +1.4 and +1.5 V.[18] The positive value shows that No^{2+} is more stable than No^{3+} and that No^{3+} is a good oxidizing agent. While the quoted values for the $E°(No^{2+}{\to}No^0)$ and $E°(No^{3+}{\to}No^0)$ vary among sources, the accepted standard estimates are −2.61 and −1.26 V.[18] It has been predicted that the value for the $E°(No^{4+}{\to}No^{3+})$ couple would be +6.5 V.[18] The Gibbs energies of formation for No^{3+} and No^{2+} are estimated to be −342 and −480 kJ·mol^{-1}, respectively.[18]

Atomic

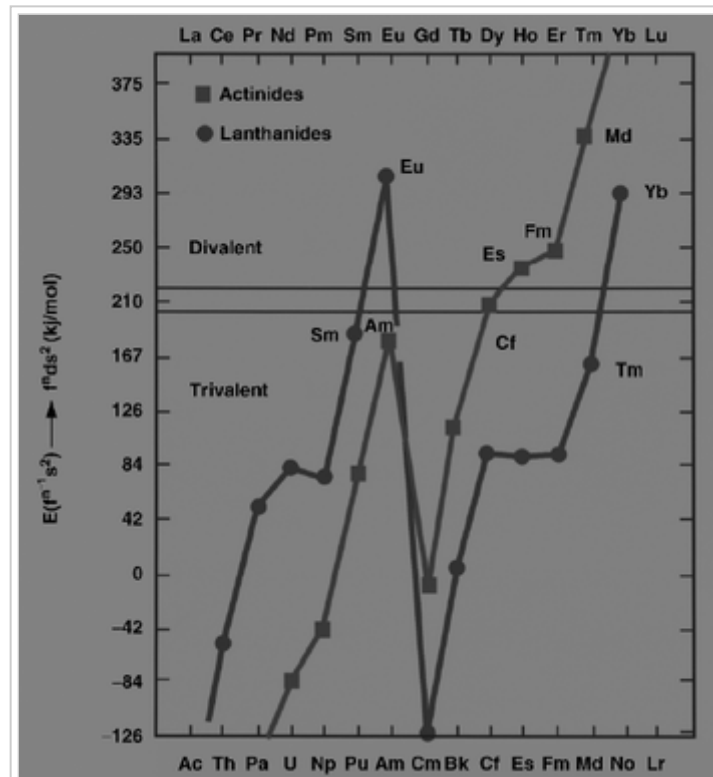A nobelium atom has 102 electrons, of which three can act as valence electrons. They are expected to be arranged in the configuration $[Rn]5f^{14}7s^2$ (ground state term symbol $^1S_0$), although experimental verification of this electron configuration had not yet been made as of 2006.[13] In forming compounds, all the three valence electrons may be lost, leaving behind a $[Rn]5f^{13}$ core: this conforms to the trend set by the other actinides with their $[Rn]5f^n$ electron configurations in the tripositive state. Nevertheless, it is more likely that only two valence electrons may be lost, leaving behind a stable $[Rn]5f^{14}$ core with a filled $5f^{14}$ shell. The first ionization potential of nobelium was measured to be at most (6.65 ± 0.07) eV in 1974, based on the assumption that the 7s electrons would ionize before the 5f ones;[20] this value has since not yet been refined further due to nobelium's scarcity and high radioactivity.[21] The ionic radius of hexacoordinate and octacoordinate No^{3+} had been preliminarily estimated in 1978 to be around 90 and 102 pm respectively;[18] the ionic radius of No^{2+} has been experimentally found to be 100 pm to two significant figures.[13] The enthalpy of hydration of No^{2+} has been calculated as 1486 kJ·mol^{-1}.[18]

Energy required to promote an f electron to the d subshell for the f-block lanthanides and actinides. Above around 210 kJ/mol, this energy is too high to be provided for by the greater crystal energy of the trivalent state and thus einsteinium, fermium, and mendelevium fom divalent metals like the lanthanides europium and ytterbium. Nobelium is also expected to form a divalent metal, but this has not yet been confirmed.[12]

Isotopes

Twelve isotopes of nobelium are known, with mass numbers 250–260 and 262; all are radioactive.[22] Additionally, nuclear isomers are known for mass numbers 251, 253, and 254.[23][24] Of these, the longest-lived isotope is ^{259}No with a half-life of 58 minutes, and the longest-lived isomer is ^{251m}No with a half-life of 1.7 seconds.[23][24] However, the still undiscovered isotope ^{261}No is predicted to have a still longer half-life of 170 min.[23][24] Additionally, the shorter-lived ^{255}No (half-life 3.1 minutes) is more often used in chemical experimentation because it can be produced in larger quantities from irradiation of californium-249 with carbon-12 ions.[22] After ^{259}No and ^{255}No, the next most stable nobelium isotopes are ^{253}No (half-life 1.62 minutes), ^{254}No (51 seconds), ^{257}No (25 seconds), ^{256}No (2.91 seconds), and ^{252}No (2.57 seconds).[22][23][24] All of the remaining nobelium isotopes have half-lives that are less than a second, and the

shortest-lived known nobelium isotope (^{250}No) has a half-life of only 0.25 milliseconds.[22][23][24] The isotope ^{254}No is especially interesting theoretically as it is in the middle of a series of prolate nuclei from ^{231}Pa to ^{279}Rg, and the formation of its nuclear isomers (of which two are known) is controlled by proton orbitals such as $2f_{5/2}$ which come just above the spherical proton shell.[25]

The half-lives of nobelium isotopes increase smoothly from ^{250}No to ^{253}No. However, a dip appears at ^{254}No, and beyond this the half-lives of even-even nobelium isotopes drop sharply as spontaneous fission becomes the dominant decay mode. For example, the half-life of ^{256}No is almost three seconds, but that of ^{258}No is only 1.2 milliseconds.[22][23][24] This shows that at nobelium, the mutual repulsion of protons poses a limit to the island of relative stability of long-lived nuclei in the actinide series.[26] The even-odd nobelium isotopes mostly continue to have longer half-lives as their mass numbers increase, with a dip in the trend at ^{257}No.[22][23][24]

External links

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