Nihonium

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Nihonium (symbol **Nh**) is a chemical element with atomic number 113. It is a synthetic element (an element that can be created in a laboratory but is not found in nature) and is extremely radioactive; its most stable known isotope, nihonium-286, has a half-life of 20 seconds. Nihonium was first reported to have been created in 2003 by the Joint Institute for Nuclear Research in Dubna, Russia, and in 2004 by a team of Japanese scientists at RIKEN. In December 2015, the International Union of Pure and Applied Chemistry (IUPAC) and the International Union of Pure and Applied Physics (IUPAP) recognized the element and assigned the priority of the discovery to RIKEN.[6] In November 2016, the IUPAC published a declaration defining the name to be *nihonium*.[7] The name comes from the common Japanese name for Japan (□□ *nihon*). On 28 November 2016, the name became official.[8][9]

In the periodic table, it is a p-block transactinide element. It is a member of the 7th period and is placed in the boron group, although it has not been confirmed to behave as the heavier homologue to thallium in the boron group. Nihonium is calculated to have some similar properties to its lighter homologues, boron, aluminium, gallium, indium, and thallium, and behave as a post-transition metal, although it should also show several major differences from them. Unlike all the other p-block elements, it may be able to involve its d-electrons in bonding, although these predictions are disputed.

Nihonium, $_{113}$Nh

General properties	
Name, symbol	nihonium, Nh
Nihonium in the periodic table	
Atomic number (Z)	113
Group, block	group 13, p-block
Period	period 7
Element category	unknown, but probably a post-transition metal
Standard atomic weight (A_r)	[286]
Electron configuration	[Rn] $5f^{14}$ $6d^{10}$ $7s^2$ $7p^1$ *(predicted)*[1]
per shell	2, 8, 18, 32, 32, 18, 3 *(predicted)*
Physical properties	
Phase	solid *(predicted)*[1][2][3]
Melting point	700 K (430 °C, 810 °F) *(predicted)*[1]
Boiling point	1430 K (1130 °C, 2070 °F) *(predicted)*[1][4]
Density near r.t.	16 g/cm^3

Isotopes

Nihonium 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. Six different isotopes of nihonium have been reported with atomic masses 278 and 282–286; they all decay through alpha decay,[27] although nihonium-284 may have an electron capture branch.[30]

Stability and half-lives

All nihonium isotopes are extremely unstable and radioactive; however, the heavier nihonium isotopes are more stable than the lighter. The most stable known nihonium isotope, ^{286}Nh, is also the heaviest known nihonium isotope; it has a half-life of 20 seconds. The isotope ^{285}Nh has been reported to also have a half-life of over a second. The isotopes ^{284}Nh and ^{283}Nh have half-lives of 0.48 and 0.10 seconds respectively. The remaining two isotopes have half-lives between 0.1 and 100 milliseconds: ^{282}Nh has a half-life of 70 milliseconds, and ^{278}Nh, the lightest known nihonium isotope, is also the shortest-lived known nihonium isotope, with a half-life of just 0.24 milliseconds. It is predicted that even heavier undiscovered nihonium isotopes could be much more stable: for example, ^{287}Nh is predicted to have a half-life of around 20 minutes,[31] close to two orders of magnitude more than that of ^{286}Nh.[27]

Theoretical estimates of alpha decay half-lives of isotopes of nihonium are in good agreement with the experimental data.[32] The undiscovered isotope ^{293}Nh has been predicted to be the most stable towards beta decay;[33] however, no known nihonium isotope has been observed to undergo beta decay.[27]

The stability of nuclei decreases greatly with the increase in atomic number after plutonium, the heaviest primordial element, so that all isotopes with an atomic number above 101 decay radioactively with a half-life under a day, with the exception of dubnium-268. Nevertheless, because of reasons not very well understood yet, there is a slight increased nuclear stability around atomic numbers 110–114, which leads to the appearance of what is known in nuclear physics as the "island of stability". This concept, proposed by University of California professor Glenn Seaborg, explains why superheavy elements last longer than predicted.[34]

Predicted properties

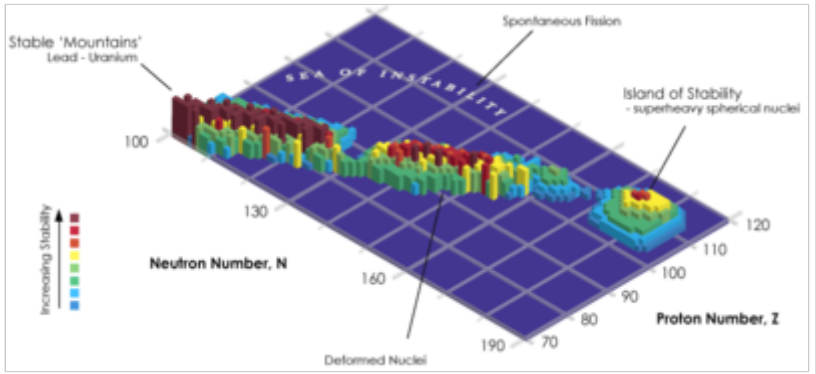
Nihonium is the first member of the 7p series of elements and the heaviest boron group element on the periodic table, below boron, aluminium, gallium, indium, and thallium. It is predicted to show many differences from its lighter homologues: a largely contributing effect is the spin–orbit (SO) interaction. It is especially strong for the superheavy elements, because their electrons move much faster than in lighter atoms, at velocities comparable to the speed of light.[36] In relation to nihonium atoms, it lowers the 7s and

	(predicted)[4]
Heat of fusion	7.61 kJ/mol *(extrapolated)*[3]
Heat of vaporization	130 kJ/mol *(predicted)*[2][4]
Atomic properties	
Oxidation states	−1, **1**, **3**, 5 *(predicted)*[1][4][5]
Ionization energies	1st: 704.9 kJ/mol *(predicted)*[1] 2nd: 2238.5 kJ/mol *(predicted)*[4] 3rd: 3203.3 kJ/mol *(predicted)*[4] (more)
Atomic radius	empirical: 170 pm *(predicted)*[1]
Covalent radius	172–180 pm *(extrapolated)*[3]
Miscellanea	
CAS Number	54084-70-7
History	
Naming	After Japan (*Nihon* in Japanese)
Discovery	RIKEN (2004, first undisputed) Joint Institute for Nuclear Research and Lawrence Livermore National Laboratory (2003, first announced)

the 7p electron energy levels (stabilizing the corresponding electrons), but two of the 7p electron energy levels are stabilized more than the other four.[37] The stabilization of the 7s electrons is called the inert pair effect, and the effect "tearing" the 7p subshell into the more stabilized and the less stabilized parts is called the subshell splitting. Computation chemists see the split as a change of the second (azimuthal) quantum number *l* from 1 to 1/2 and 3/2 for the more stabilized and less stabilized parts of the 7p subshell, respectively.[36][note 1] For many theoretical purposes, the valence electron configuration may be represented to reflect the 7p subshell split as $7s^2 7p_{1/2}{}^1$.[1] These effects stabilize lower oxidation states: the first ionization energy of nihonium is expected to be 7.306 eV, the highest among the boron group elements. Hence, the most stable oxidation state of nihonium is predicted to be the +1 state,[1] and nihonium is expected to be less reactive than thallium.[4] Differences for other electron levels also exist. For example, the 6d electron levels (also split in halves, with four being $6d_{3/2}$ and six being $6d_{5/2}$) are both raised, so that they are close in energy to the 7s ones.[37] Thus, the 6d electron levels, being destabilized, should still be able to participate in chemical reactions in nihonium[1] (as well as in the next 7p element, flerovium),[4] thus making it behave in some ways like transition metals and allow higher oxidation states.[1] Nihonium should hence also be able to show stable +3 and possibly also +5 oxidation states. However, the +3 state should still be less stable than the +1 state, following periodic trends. Nihonium should be the most electronegative among all the boron group elements:[1] for example, in the compound NhTs, the negative charge is expected to be on the nihonium atom rather than the tennessine atom, the opposite of what would be expected from simple periodicity.[35] The electron affinity of nihonium is calculated to be around 0.68 eV; in comparison, that of thallium is 0.4 eV.[1] The high electron affinity and electronegativity of nihonium are due to it being only one electron short of the closed-shell valence electron configuration of flerovium ($7s^2 7p_{1/2}{}^2$):[1] this would make the −1 oxidation state of nihonium more stable than that of its lighter congener thallium.[5] The standard electrode potential for the Nh^+/Nh couple is predicted to be −0.6 V.[4]

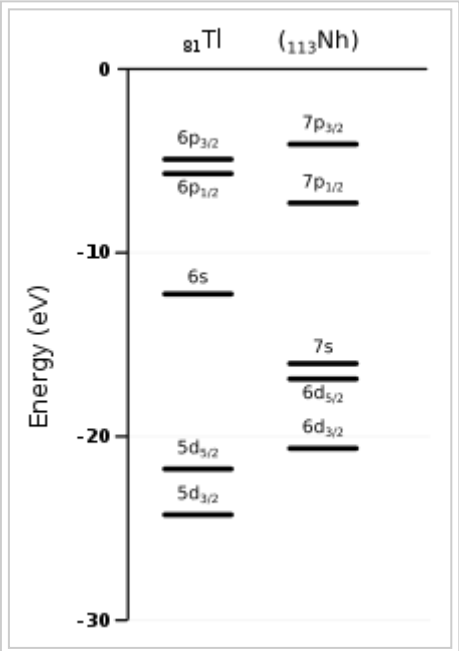
Most stable isotopes of nihonium

iso	NA	half-life	DM	DE (MeV)	DP
^{286}Nh	syn	20 s	α	9.63	^{282}Rg
^{285}Nh	syn	5.5 s	α	9.74, 9.48	^{281}Rg
^{284}Nh	syn	0.48 s	α	10.00	^{280}Rg
			EC		^{284}Cn
^{283}Nh	syn	0.10 s	α	10.12	^{279}Rg
^{282}Nh	syn	70 ms	α	10.63	^{278}Rg
^{278}Nh	syn	0.24 ms	α	11.68	^{274}Rg



3-dimensional rendering of the theoretical island of stability around N=178 and Z=112

The simplest possible nihonium compound is the monohydride, NhH. The bonding is provided by the $7p_{1/2}$ electron of nihonium and the 1s electron of hydrogen. However, the SO interaction causes the binding energy of nihonium monohydride to be reduced by about 1 eV[1] and the nihonium–hydrogen bond length to decrease as the bonding $7p_{1/2}$ orbital is relativistically contracted. This is exceptional in the 7p series of elements; all other MH (M = Fl, Mc, Lv, Ts, Og) molecules have relativistic expansion of the bond length instead of contraction.[38] The analogous monofluoride (NhF) should also exist.[35] Nihonium should also be able to form the trihydride (NhH_3), trifluoride (NhF_3), and trichloride ($NhCl_3$), with nihonium in the +3 oxidation state. Because the 6d electrons are involved in bonding instead of the 7s ones, these molecules are predicted to be T-shaped and not trigonal planar. Although the polyfluoride anion NhF_6^- should be stable, the corresponding neutral fluoride NhF_5 should be unstable, spontaneously decomposing into the trifluoride and elemental fluorine. Nihonium(I) is predicted to be more similar to silver(I) than thallium(I):[1] the Nh^+ ion is expected to more willingly bind anions, so that NhCl should be quite soluble in an excess of hydrochloric acid or in ammonia while TlCl is not. Additionally, in contrast to the strongly basic TlOH, nihonium(I) should instead form Nh_2O, which would be weakly water-soluble and readily ammonia-soluble.[4]



Atomic energy levels of outermost s, p, and d electrons of thallium and nihonium[35]

Nihonium is expected to be much denser than thallium, having a predicted density of about 16 to 18 g/cm^3, due to the relativistic stabilization and contraction of its 7s and $7p_{1/2}$ orbitals.[1][35] This is because calculations estimate it to have an atomic radius of about 170 pm, the same as that of thallium, even though periodic trends would predict it to have an atomic radius larger than that of thallium due to it being one period further down in the periodic table.[1] The melting and boiling points of nihonium are not definitely known, but have been calculated to be 430 °C and 1100 °C respectively, exceeding the values for gallium, indium, and thallium, following periodic trends.[1][2]

Experimental chemistry

Unambiguous determination of the chemical characteristics of nihonium has yet to have been established.[39][40] The isotopes ^{284}Nh, ^{285}Nh, and ^{286}Nh have half-lives long enough for chemical investigation. It is theoretically predicted that nihonium should have an enthalpy of sublimation around 150 kJ/mol and an enthalpy of adsorption on a gold surface around −159 kJ/mol.[40] From 2010 to 2012, some preliminary chemical experiments were performed to determine the volatility of nihonium. The reaction used was ^{243}Am(^{48}Ca,3n)^{288}Mc; the isotope ^{288}Mc has a short half-life and would quickly decay to the longer-lived ^{284}Nh, which would

be chemically investigated. Teflon capillaries at 70 °C connecting the recoil chamber, where the nihonium atoms were synthesized, and the gold-covered detectors: the nihonium atoms would be carried along the capillaries by a carrier gas. While about ten to twenty atoms of ^{284}Nh were produced, none of these atoms were registered by the gold-covered detectors, suggesting either that nihonium was similar in volatility to the noble gases or, more plausibly, that pure nihonium was not very volatile and thus could not efficiently pass through the Teflon capillaries at 70 °C.[40] Formation of the hydroxide NhOH would ease the transport, as NhOH is expected to be more volatile than elemental nihonium, and this reaction could be facilitated by adding more water vapor into the carrier gas. However, it seems likely that this formation is not kinetically favored, so that one would need to use the longer-lived isotope ^{286}Nh in future experiments.[40]

Source

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