Moscovium

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Moscovium (element symbol: **Mc**) is a superheavy synthetic element with the atomic number 115. It was first synthesized in 2003 by a joint team of Russian and American scientists at the Joint Institute for Nuclear Research (JINR) in Dubna, Russia. In December 2015, it was recognized as one of four new elements by the Joint Working Party of international scientific bodies IUPAC and IUPAP. On 28 November 2016, it was officially named.[5][6][7]

Moscovium is an extremely radioactive element: its most stable known isotope, moscovium-289, has a half-life of only 220 milliseconds.[8] In the periodic table, it is a p-block transactinide element. It is a member of the 7th period and is placed in group 15 as the heaviest pnictogen, although it has not been confirmed to behave as a heavier homologue of the pnictogen bismuth. Moscovium is calculated to have some properties similar to its lighter homologues, nitrogen, phosphorus, arsenic, antimony, and bismuth, and to be a post-transition metal, although it should also show several major differences from them. About 100 atoms of moscovium have been observed to date, all of which have been shown to have mass numbers from 287 to 290.

Moscovium, $_{115}$Mc

General properties	
Name, symbol	moscovium, Mc
Moscovium in the periodic table	
Atomic number (*Z*)	115
Group, block	group 15 (pnictogens), p-block
Period	period 7
Element category	unknown, but probably a post-transition metal
Standard atomic weight (A_r)	[289]
Electron configuration	[Rn] $5f^{14}$ $6d^{10}$ $7s^2$ $7p^3$ *(predicted)*[1]
per shell	2, 8, 18, 32, 32, 18, 5 *(predicted)*
Physical properties	
Phase	solid *(predicted)*[1]
Melting point	670 K (400 °C, 750 °F) *(predicted)*[1][2]
Boiling point	~1400 K (~1100 °C, ~2000 °F) *(predicted)*[1]
Density near r.t.	13.5 g/cm^3 *(predicted)*[2]

Predicted properties

Nuclear stability and isotopes

Moscovium is expected to be in the middle of an island of stability centered on copernicium (element 112) and flerovium (element 114): the reasons for the presence of this island, however, are still not well understood.[25][26] Due to the expected high fission barriers, any nucleus within this island of stability exclusively decays by alpha decay and perhaps some electron capture and beta decay.[2] Although the known isotopes of moscovium do not actually have enough neutrons to be on the island of stability, they can be seen to approach the island as in general, the heavier isotopes are the longer-lived ones.[8][11]

The hypothetical isotope ^{291}Mc is an especially interesting case as it has only one neutron more than the heaviest known moscovium isotope, ^{290}Mc. It could plausibly be synthesized as the daughter of tennessine-295, which in turn could be made from the reaction ^{249}Bk(^{48}Ca,2n)^{295}Ts.[25] Calculations show that it may have a significant electron capture or positron emission decay mode in addition to alpha decaying and also have a relatively long half-life of several seconds. This would produce ^{291}Fl, ^{291}Nh, and finally ^{291}Cn which is expected to be in the middle of the island of stability and have a half-life of about 1200 years, affording the most likely hope of reaching the middle of the island using current technology. Possible drawbacks are that the cross section of the production reaction of ^{295}Ts is expected to be low and the decay properties of superheavy nuclei this close to the line of beta stability are largely unexplored.[25]

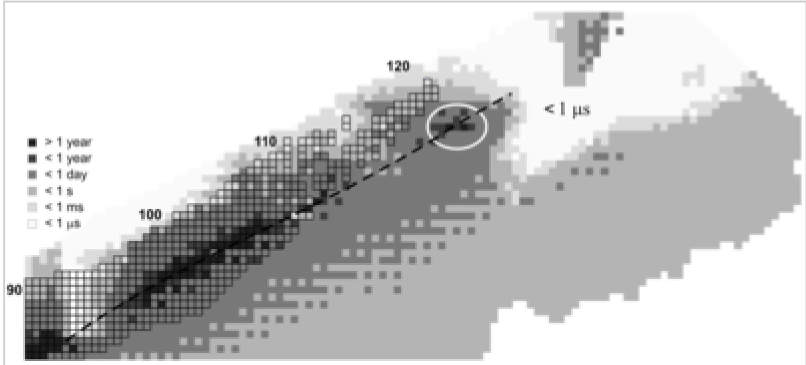
Other possibilities to synthesize nuclei on the island of stability include quasifission (partial fusion followed by fission) of a massive nucleus.[27] Such nuclei tend to fission, expelling doubly magic or nearly doubly magic fragments such as calcium-40, tin-132, lead-208, or bismuth-209.[28] Recently it has been shown that the multi-nucleon transfer reactions in collisions of actinide nuclei (such as uranium and curium) might be used to synthesize the neutron-rich superheavy nuclei located at the island of stability,[27] although formation of the lighter elements nobelium or seaborgium is more favored.[25] One last possibility to synthesize isotopes near the island is to use controlled nuclear explosions to create a neutron flux high enough to bypass the gaps of instability at $^{258–260}$Fm and at mass number 275 (atomic numbers 104 to 108), mimicking the r-process in which the actinides were first produced in nature and the gap of instability around radon bypassed.[25] Some such isotopes (especially ^{291}Cn and ^{293}Cn) may even have been synthesized in nature, but would have decayed away far too quickly (with half-lives of only thousands of years) and be produced in far too small quantities (about 10^{-12} the abundance of lead) to be detectable as primordial nuclides today outside cosmic rays.[25]

Physical and atomic

Heat of fusion	5.90–5.98 kJ/mol *(extrapolated)*[3]
Heat of vaporization	138 kJ/mol *(predicted)*[2]
Atomic properties	
Oxidation states	**1**, **3** *(prediction)*[1][2]
Ionization energies	1st: 538.4 kJ/mol *(predicted)*[1] 2nd: 1756.0 kJ/mol *(predicted)*[2] 3rd: 2653.3 kJ/mol *(predicted)*[2] (more)
Atomic radius	empirical: 187 pm *(predicted)*[1][2]
Covalent radius	156–158 pm *(extrapolated)*[3]
Miscellanea	
CAS Number	54085-64-2
History	
Naming	After Moscow region
Discovery	Joint Institute for Nuclear Research and Lawrence Livermore National Laboratory (2003)
Most stable isotopes of moscovium	

iso	NA	half-life	DM	DE (MeV)	DP
^{290}Mc	syn	16 ms[4]	α	9.95	^{286}Nh
^{289}Mc	syn	220 ms[4]	α	10.31	^{285}Nh
^{288}Mc	syn	87 ms	α	10.46	^{284}Nh
^{287}Mc	syn	32 ms	α	10.59	^{283}Nh

In the periodic table, moscovium is a member of group 15, the pnictogens, below nitrogen, phosphorus, arsenic, antimony, and bismuth. Every previous pnictogen has five electrons in its valence shell, forming a valence electron configuration of ns^2np^3. In moscovium's case, the trend should be continued and the valence electron configuration is predicted to be $7s^27p^3$;[1] therefore, moscovium will behave similarly to its lighter congeners in many respects. However, notable differences are likely to arise; a largely contributing effect is the spin–orbit (SO) interaction—the mutual interaction between the electrons' motion and spin. 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.[29] In relation to moscovium atoms, it lowers the 7s and the 7p electron energy levels (stabilizing the corresponding electrons), but two of the 7p electron energy levels are stabilized more than the other four.[30] 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 subshell splitting. Computation chemists see the split as a change of the second (azimuthal) quantum number *l* from 1 to ½ and ³⁄₂ for the more stabilized and less stabilized parts of the 7p subshell, respectively.[29][a] For many theoretical purposes, the valence electron configuration may be represented to reflect the 7p subshell split as $7s^27p^2_{1/2}7p^1_{3/2}$.[1] These effects cause moscovium's chemistry to be somewhat different from that of its lighter congeners.



The expected location of the island of stability. The dotted line is the line of beta stability.

The valence electrons of moscovium fall into three subshells: 7s (two electrons), $7p_{1/2}$ (two electrons), and $7p_{3/2}$ (one electron). The first two of these are relativistically stabilized and hence behave as inert pairs, while the last is relativistically destabilized and can easily participate in chemistry.[1] (The 6d electrons are not destabilized enough to participate chemically, although this may still be possible in the two previous elements nihonium and flerovium.)[2] Thus, the +1 oxidation state should be favored, like Tl^+, and consistent with this the first ionization potential of moscovium should be around 5.58 eV, continuing the trend towards lower ionization potentials down the pnictogens.[1] Moscovium and nihonium both have one electron outside a quasi-closed shell configuration that can be delocalized in the metallic state: thus they should have similar melting and boiling points (both melting around 400 °C and boiling around 1100 °C) due to the strength of their metallic bonds being similar.[2] Additionally, the predicted ionization potential, ionic radius (1.5 Å for Mc^+; 1.0 Å for Mc^{3+}), and polarizability of Mc^+ are expected to be more similar to Tl^+ than its true congener Bi^{3+}.[2] Moscovium should be a dense metal due to its high atomic weight, with a density around 13.5 g/cm^3.[2] The electron of the hydrogen-like moscovium atom (oxidized so that it only has one electron, Mc^{114+}) is expected to move so fast that it has a mass 1.82 times that of a stationary electron, due to relativistic effects. For comparison, the figures for hydrogen-like bismuth and antimony are expected to be 1.25 and 1.077 respectively.[29]

Chemical

Moscovium is predicted to be the third member of the 7p series of chemical elements and the heaviest member of group 15 (VA) in the Periodic Table, below bismuth. In this group, each member is known to portray the group oxidation state of +5 but with differing stability. For nitrogen, the +5 state is mostly a formal explanation of molecules like N_2O_5: it is very difficult to have five covalent bonds to nitrogen due to the inability of the small nitrogen atom to accommodate five ligands. The +5 state is well represented for the essentially non-relativistic typical pnictogens phosphorus, arsenic, and antimony. However, for bismuth it becomes rare due to the relativistic stabilization of the 6s orbitals known as the inert pair effect, so that the 6s electrons are reluctant to bond chemically. It is expected that moscovium will have an inert pair effect for both the 7s and the $7p_{1/2}$ electrons, as the binding energy of the lone $7p_{3/2}$ electron is noticeably lower than that of the $7p_{1/2}$ electrons. Nitrogen(I) and bismuth(I) are known but rare and moscovium(I) is likely to show some unique properties,[31] probably behaving more like thallium(I) than bismuth(I).[2] Because of spin-orbit coupling, flerovium may display closed-shell or noble gas-like properties; if this is the case, moscovium will likely be typically monovalent as a result, since the cation Mc^+ will have the same electron configuration as flerovium, perhaps giving moscovium some alkali metal character.[2] However, the Mc^{3+} cation would behave like its true lighter homolog Bi^{3+}.[2] The 7s electrons are too stabilized to be able to contribute chemically and hence the +5 state should be impossible and moscovium may be considered to have only three valence electrons.[2] Moscovium would be quite a reactive metal, with a standard reduction potential of −1.5 V for the Mc^+/Mc couple.[2]

The chemistry of moscovium in aqueous solution should essentially be that of the Mc^+ and Mc^{3+} ions. The former should be easily hydrolyzed and not be easily complexed with halides, cyanide, and ammonia.[2] Moscovium(I) hydroxide (McOH), carbonate (Mc_2CO_3), oxalate ($Mc_2C_2O_4$), and fluoride (McF) should be soluble in water; the sulfide (Mc_2S) should be insoluble; and the chloride (McCl), bromide (McBr), iodide (McI), and thiocyanate (McSCN) should be only slightly soluble, so that adding excess hydrochloric acid would not noticeably affect the solubility of moscovium(I) chloride.[2] Mc^{3+} should be about as stable as Tl^{3+} and hence should also be an important part of moscovium chemistry, although its closest homolog among the elements should be its lighter congener Bi^{3+}.[2] Moscovium(III) fluoride (McF_3) and thiozonide (McS_3) should be insoluble in water, similar to the corresponding bismuth compounds, while moscovium(III) chloride ($McCl_3$), bromide ($McBr_3$), and iodide (McI_3) should be readily soluble and easily hydrolyzed to form oxyhalides such as McOCl and McOBr, again analogous to bismuth.[2] Both moscovium(I) and moscovium(III) should be common oxidation states and their relative stability should depend greatly on what they are complexed with and the likelihood of hydrolysis.[2]

Experimental chemistry

Unambiguous determination of the chemical characteristics of moscovium has yet to have been established.[32][33] In 2011, experiments were conducted to create nihonium, flerovium, and moscovium isotopes in the reactions between calcium-48 projectiles and targets of americium-243 and plutonium-244. However, the targets included lead and bismuth impurities and hence some isotopes of bismuth and polonium were generated in nucleon transfer reactions. This, while an unforeseen complication, could give information that would help in the future chemical investigation of the heavier homologs of bismuth and polonium, which are respectively moscovium and livermorium.[33] The produced nuclides bismuth-213 and polonium-212m were transported as the hydrides $^{213}BiH_3$ and $^{212m}PoH_2$ at 850 °C through a quartz wool filter unit held with tantalum, showing that these hydrides were surprisingly thermally stable, although their heavier congeners McH_3 and LvH_2 would be expected to be less thermally stable from simple extrapolation of periodic trends in the p-block.[33] Further calculations on the stability and electronic structure of BiH_3, McH_3, PoH_2, and LvH_2 are needed before chemical investigations take place. However, moscovium and livermorium are expected to be volatile enough as pure elements for them to be chemically investigated in the near future. The chief barrier to their chemical investigation at present is the lack of known isotopes of these elements which are long-lived enough, with only ^{289}Mc being barely usable with current methods.[33]

Source

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