= Ununennium =

Ununennium , also known as eka @-@ francium or simply element 119 , is the hypothetical chemical element with atomic number 119 and symbol Uue . Ununennium and Uue are the temporary systematic IUPAC name and symbol , until a permanent name is decided upon . In the periodic table of the elements , it is expected to be an s @-@ block element , an alkali metal , and the first element in the eighth period .

Ununennium is the element with the lowest atomic number that has not yet been synthesized . Multiple attempts have been made by American , German , and Russian teams to synthesize this element : they have all been unsuccessful , as experimental evidence has shown that the synthesis of ununennium will likely be far more difficult than that of the previous elements , and may even be the penultimate element that can be synthesized with current technology . Its position as the seventh alkali metal suggests that it would have similar properties to its lighter congeners , lithium , sodium , potassium , rubidium , caesium , and francium ; however , relativistic effects may cause some of its properties to differ from those expected from a straight application of periodic trends . For example , ununennium is expected to be less reactive than caesium and francium and to be closer in behavior to potassium or rubidium , and while it should show the characteristic + 1 oxidation state of the alkali metals , it is also predicted to show the + 3 oxidation state unknown in any other alkali metal .

= = History = =

Superheavy elements are produced by nuclear fusion . These fusion reactions can be divided into " hot " and " cold " fusion , depending on the excitation energy of the compound nucleus produced . 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 fission , or alternatively evaporate several (3 to 5) neutrons . In cold fusion reactions (which use heavier projectiles , typically from the fourth period , and lighter targets , usually lead and bismuth) , the fused nuclei produced have a relatively low 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 . However , hot fusion reactions tend to produce more neutron @-@ rich products because the actinides have the highest neutron @-@ to @-@ proton ratios of any elements that can presently be made in macroscopic quantities .

Ununennium and unbinilium (elements 119 and 120) are the lightest elements that have not yet been synthesized , and attempts to synthesize them would push the limits of current technology , due to the decreasing cross sections of the production reactions and their probably short half @-@ lives , expected to be on the order of microseconds . Heavier elements would likely be too short @-@ lived to be detected with current technology : they would decay within a microsecond , before reaching the detectors . Previously , important help (characterized as " silver bullets ") in the synthesis of superheavy elements came from the deformed nuclear shells around hassium @-@ 270 which increased the stability of surrounding nuclei , and the existence of the quasi @-@ stable neutron @-@ rich isotope calcium @-@ 48 which could be used as a projectile to produce more neutron @-@ rich isotopes of superheavy elements . The more neutron @-@ rich a superheavy nuclide is , the closer it is expected to be to the sought @-@ after island of stability . Even so , the synthesized isotopes still have fewer neutrons than those expected to be in the island of stability . Furthermore , using calcium @-@ 48 to synthesize ununennium would require a target of einsteinium @-@ 253 or -254 , which is very difficult to produce in sufficiently large quantities . More practical production of further superheavy elements would require projectiles heavier than 48Ca .

= = = Synthesis attempts = = =

The synthesis of ununennium was first attempted in 1985 by bombarding a target of einsteinium

@-@ 254 with calcium @-@ 48 ions at the superHILAC accelerator at Berkeley , California :
254
99Es + 48
20Ca ? 302
119Uue * ? no atoms
No atoms were identified , leading to a limiting cross section of 300 nb . Later calculations suggest that the cross section of the 3n reaction (which would result in 299Uue and three neutrons as products) would actually be six hundred thousand times lower than this upper bound , at 0 @.@ 5 pb .

As ununennium is the lightest undiscovered element , it has been the target of synthesis experiments by both German and Russian teams in recent years . The Russian experiments were conducted in 2011 , and no results were released , strongly implying that no ununennium atoms were identified . From April to September 2012 , an attempt to synthesize the isotopes 295Uue and 296Uue was made by bombarding a target of berkelium @-@ 249 with titanium @-@ 50 at the GSI Helmholtz Centre for Heavy Ion Research in Darmstadt , Germany . Based on the theoretically predicted cross @-@ section , it was expected that an ununennium atom would be synthesized within five months of the beginning of the experiment .
249
97Bk + 50
22Ti ? 299
119Uue * ? 296
119Uue + 3 1
0n
249
97Bk + 50
22Ti ? 299
119Uue * ? 295
119Uue + 4 1
0n
The experiment was originally planned to continue to November 2012 , but was stopped early to make use of the 249Bk target to confirm the synthesis of ununseptium (thus changing the projectiles to 48Ca) . This reaction between 249Bk and 50Ti was predicted to be the most favorable practical reaction for formation of ununennium , as it is rather asymmetrical , though also somewhat cold . (The reaction between 254Es and 48Ca would be superior , but preparing milligram quantities of 254Es for a target is difficult .) Nevertheless , the necessary change from the " silver bullet " 48Ca to 50Ti divides the expected yield of ununennium by about twenty , as the yield is strongly dependent on the asymmetry of the fusion reaction .

Due to the predicted short half @-@ lives , the GSI team used new " fast " electronics capable of registering decay events within microseconds . No ununennium atoms were identified , implying a limiting cross @-@ section of 70 fb . The predicted actual cross @-@ section is around 40 fb , which is at the limits of current technology .

= = = Naming = = =

Using Mendeleev 's nomenclature for unnamed and undiscovered elements , ununennium should be known as eka @-@ francium . Using the 1979 IUPAC recommendations , the element should be temporarily called ununennium (symbol Uue) until it is discovered , the discovery is confirmed , and a permanent name chosen . Although widely used in the chemical community on all levels , from chemistry classrooms to advanced textbooks , the recommendations are mostly ignored among scientists who work theoretically or experimentally on superheavy elements , who call it " element 119 " , with the symbol (119) or 119 .

= = Predicted properties = =

= = = Nuclear stability and isotopes = = =

The stability of nuclei decreases greatly with the increase in atomic number after curium , element 96 , whose half @-@ life is four orders of magnitude longer than that of any currently known higher @-@ numbered element . All isotopes with an atomic number above 101 undergo radioactive decay with half @-@ lives of less than 30 hours . No elements with atomic numbers above 82 (after lead) have stable isotopes . Nevertheless , because of reasons not yet well understood , there is a slight increase of 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 .

The alpha @-@ decay half @-@ lives predicted for 291 ? 307Uue are on the order of microseconds . The longest alpha @-@ decay half @-@ life predicted is ~ 485 microseconds for the isotope 294Uue . When factoring in all decay modes , the predicted half @-@ lives drop further to only tens of microseconds . This has consequences for the synthesis of ununennium , as isotopes with half @-@ lives below one microsecond would decay before reaching the detector . Nevertheless , new theoretical models show that the expected gap in energy between the proton orbitals 2f7 / 2 (filled at element 114) and 2f5 / 2 (filled at element 120) is smaller than expected , so that element 114 no longer appears to be a stable spherical closed nuclear shell , and this energy gap may increase the stability of elements 119 and 120 . The next doubly magic nucleus is now expected to be around the spherical 306Ubb (element 122) , but the expected low half @-@ life and low production cross section of this nuclide makes its synthesis challenging .

= = = Atomic and physical = = =

Being the first period 8 element , ununennium is predicted to be an alkali metal , below lithium , sodium , potassium , rubidium , caesium , and francium . Each of these elements has one valence electron in the outermost s @-@ orbital (valence electron configuration ns1) , which is easily lost in chemical reactions to form the + 1 oxidation state : thus the alkali metals are very reactive elements . Ununennium is predicted to continue the trend and have a valence electron configuration of 8s1 . It is therefore expected to behave much like its lighter congeners ; however , it is also predicted to differ from the lighter alkali metals in some properties .

The main reason for the predicted differences between ununennium and the other alkali metals is the spin ? orbit (SO) interaction ? the mutual interaction between the electrons ' motion and spin . The SO interaction is especially strong for the superheavy elements because their electrons move faster ? at velocities comparable to the speed of light ? than those in lighter atoms . In ununennium atoms , it lowers the 7p and 8s electron energy levels , stabilizing the corresponding electrons , but two of the 7p electron energy levels are more stabilized than the other four . The effect is called subshell splitting , as it splits the 7p subshell into more @-@ stabilized and the less @-@ stabilized parts . Computational chemists understand 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 . Thus , the outer 8s electron of ununennium is stabilized and becomes harder to remove than expected , while the 7p3 / 2 electrons are correspondingly destabilized , perhaps allowing them to participate in chemical reactions . This stabilization of the outermost s @-@ orbital (already significant in francium) is the key factor affecting ununennium 's chemistry , and causes all the trends for atomic and molecular properties of alkali metals to reverse direction after caesium .

Due to the stabilization of its outer 8s electron , ununennium 's first ionization energy ? the energy required to remove an electron from a neutral atom ? is predicted to be 4 @.@ 53 eV , higher than those of the known alkali metals from potassium onward . This effect is so large that unbiunium (element 121) is predicted to have a lower ionization energy of 4 @.@ 45 eV , so that the alkali

metal in period 8 would not have the lowest ionization energy in the period , as is true for all previous periods . Ununennium 's electron affinity is expected to be far greater than that of caesium and francium ; indeed , ununennium is expected to have an electron affinity higher than all the alkali metals lighter than it . Relativistic effects also cause a very large drop in the polarizability of ununennium , to 169 @.@ 7 a.u. Indeed , the static dipole polarisability (?D) of ununennium , a quantity for which the impacts of relativity are proportional to the square of the element 's atomic number , has been calculated to be small and similar to that of sodium .

The electron of the hydrogen @-@ like ununennium atom ? oxidized so it has only one electron , Uue118 + ? is predicted to move so quickly that its mass is 1 @.@ 99 times that of a non @-@ moving electron , a feature coming from the relativistic effects . For comparison , the figure for hydrogen @-@ like francium is 1 @.@ 29 and the figure for hydrogen @-@ like caesium is 1 @.@ 091 . According to simple extrapolations of relativity laws , that indirectly indicates the contraction of the atomic radius to around 240 pm , very close to that of rubidium (247 pm) ; the metallic radius is also correspondingly lowered to 260 pm . The ionic radius of Uue + is expected to be 180 pm .

Ununennium is predicted to have a melting point between 0 ° C and 30 ° C : thus it may be a liquid at room temperature . It is not known whether this continues the trend of decreasing melting points down the group , as francium 's melting point is known so poorly , having been variously been stated to be around 23 ° C or 27 ° C , with both values very close to the caesium value (28 @.@ 5 ° C) , possibly due to the extreme heat generated by francium 's radioactive decay . The boiling point of ununennium is expected to be around 630 ° C , which is lower than that of all the previous elements in the group , following the downward periodic trend . The density of ununennium has been variously predicted to be between 3 and 4 g · cm ? 3 , continuing the trend of increasing density down the group , using the predicted value for francium between 2 @.@ 8 and 3 @.@ 0 g · cm ? 3 .

= = = Chemical = = =

The chemistry of ununennium is predicted to be similar to that of the alkali metals , but it would probably behave more like potassium or rubidium than caesium or francium . This is unusual as periodic trends , ignoring relativistic effects , would predict ununennium to be even more reactive than caesium and francium . This lowered reactivity is due to the relativistic stabilization of ununennium 's valence electron , increasing ununennium 's first ionization energy and decreasing the metallic and ionic radii ; this effect is already seen for francium. the chemistry of ununennium in the + 1 oxidation state should be more similar to the chemistry of rubidium than to that of francium . On the other hand , the ionic radius of the Uue + ion is predicted to be larger than that of Rb + , because the 7p orbitals are destabilized and are thus larger than the p @-@ orbitals of the lower shells . Ununennium may also show the + 3 oxidation state , which is not seen in any other alkali metal , in addition to the + 1 oxidation state that is characteristic of the other alkali metals and is also the main oxidation state of all the known alkali metals : this is because of the destabilization and expansion of the 7p3 / 2 spinor , causing its outermost electrons to have a lower ionization energy than what would otherwise be expected . Many ununennium compounds are expected to have a large covalent character , due to the involvement of the 7p3 / 2 electrons in the bonding : this effect is also seen to a lesser extent in francium , which shows some 6p3 / 2 contribution to the bonding in francium superoxide (FrO2) . Thus , instead of ununennium being the most electropositive element , as a simple extrapolation would seem to indicate , caesium instead retains this position , with ununennium 's electronegativity most likely being close to sodium 's (0 @.@ 93 on the Pauling scale) .

In the gas phase , and at very low temperatures in the condensed phase , the alkali metals form covalently bonded diatomic molecules . The metal ? metal bond lengths in these M2 molecules increase down the group from Li2 to Cs2 , but then decrease after that to Uue2 , due to the aforementioned relativistic effects that stabilize the 8s orbital . The opposite trend is shown for the metal ? metal bond @-@ dissociation energies . The Uue ? Uue bond should be slightly stronger than the K ? K bond . From these M2 dissociation energies , the enthalpy of sublimation (?Hsub) of ununennium is predicted to be 94 kJ · mol ? 1 (the value for francium should be around 77 kJ · mol

? 1) .

The Uue ? Au bond should be the weakest of all bonds between gold and an alkali metal , but should still be stable . This gives extrapolated medium @-@ sized adsorption enthalpies (? ?Hads) of 106 kJ · mol ? 1 on gold (the francium value should be 136 kJ · mol ? 1) , 76 kJ · mol ? 1 on platinum , and 63 kJ · mol ? 1 on silver , the smallest of all the alkali metals , that demonstrate that it would be feasible to study the chromatographic adsorption of ununennium onto surfaces made of noble metals . The enthalpy of adsorption of ununennium on a Teflon surface is predicted to be 17 @.@ 6 kJ · mol ? 1 , which would be the lowest among the alkali metals : this information would be very useful for future chemistry experiments on ununennium . The ?Hsub and ? ?Hads values are not proportionally related for the alkali metals , as they change in opposite directions as atomic number increases .