= Ununseptium =

Ununseptium is a superheavy artificial chemical element with an atomic number of 117 and a temporary symbol of Uus . Also known as eka @-@ astatine or element 117 , it is the second @-@ heaviest known element and penultimate element of the 7th period of the periodic table . As of 2016 , fifteen ununseptium atoms have been observed : six when it was first synthesized in 2010 , seven in 2012 , and two in 2014 .

The discovery of ununseptium was announced in Dubna , Russia , by a Russian ? American collaboration in 2010 , which makes it the most recently discovered element as of 2016 . One of its daughter isotopes was created directly in 2011 , partially confirming the results of the experiment . The experiment itself was repeated successfully by the same collaboration in 2012 and by a joint German ? American team in 2014 . In 2015 , the Joint Working Party of the International Union of Pure and Applied Chemistry and the International Union of Pure and Applied Physics , which evaluates claims of discovery of new elements , has recognized the element and assigned the priority to the Russian ? American team . In June 2016 , the IUPAC published a declaration stating that the discoverers suggested a name of tennessine (/ ?t?n?sa?n / or / ?t?n?si?n /) , symbol Ts , named after Tennessee , United States . The name is set to be formally accepted in or after November 2016 . " Ununseptium " is a temporary systematic element name formed from Latin roots " one " , " one " , and " seven " ; it is intended to be used until a permanent one is assigned . The working name " element 117 " is commonly used by researchers and in the literature .

Ununseptium may be located in the " island of stability " , a concept that explains why some superheavy elements are more stable compared to an overall trend of decreasing stability for elements beyond lead on the periodic table . The synthesized ununseptium atoms have lasted tens and hundreds of milliseconds . In the periodic table , ununseptium is expected to be a member of group 17 , all other members of which are halogens . Some of its properties are likely to be significantly different from those of the halogens due to relativistic effects . Unlike the halogens , ununseptium is likely to neither commonly form anions nor achieve high oxidation states . A few key properties , such as its melting and boiling points and its first ionization energy , are nevertheless expected to follow the periodic trends of the halogens .

= = History = =

= = = Pre @-@ discovery = = =

In December 2004 , the Joint Institute for Nuclear Research (JINR) team in Dubna , Moscow Oblast , Russia , proposed a joint experiment with the Oak Ridge National Laboratory (ORNL) in Oak Ridge , Tennessee , United States , to synthesize element 117 ? so @-@ called for the 117 protons in its nucleus . Their proposal involved fusing a berkelium (element 97) target and a calcium (element 20) beam , conducted via bombardment of the berkelium target with calcium nuclei . The ORNL ? then world 's only producer of berkelium ? could not then provide the element , as they had temporarily ceased production , and re @-@ initiating it again would be too costly . Plans to synthesize element 117 were suspended in favor of the synthesis of element 118 , which was produced earlier by bombarding a californium target with calcium . The required berkelium @-@ 249 is a by @-@ product in californium @-@ 252 production , and obtaining the required amount of berkelium was an even more difficult task than obtaining that of californium , as well as costly : it would cost around 3 @.@ 5 million dollars , and the parties agreed to wait for a commercial order of californium production , from which berkelium could be extracted .

The JINR team sought to use berkelium because calcium @-@ 48 , the isotope of calcium used in the beam , has 20 protons and 28 neutrons , making a neutron ? proton ratio of 1 @.@ 4 ; and it is the lightest stable or near @-@ stable nucleus with such a large neutron excess . The second @-@ lightest such nucleus , palladium @-@ 110 (46 protons , 64 neutrons , neutron ? proton ratio of 1 @.@ 391) , is much heavier . Thanks to the neutron excess , the resulting nuclei were expected to

be heavier and closer to the sought @-@ after island of stability . Since ununseptium has 117 protons in its nucleus and calcium has 20 , they needed to use berkelium , which has 97 protons in its nucleus .

In February 2005 , the leader of the JINR team ? Yuri Oganessian ? held a colloquium at ORNL and attended a symposium at Vanderbilt University (Nashville , Tennessee , U.S.) celebrating the career of a long @-@ standing collaborator of Oganessian , Joseph Hamilton , where Oganessian , Hamilton , and James Roberto (then the deputy director for science and technology at Oak Ridge) established a collaboration between JINR , ORNL , and Vanderbilt ; the team at the Lawrence Livermore National Laboratory (LLNL) in Livermore , California , U.S. , was soon invited to join .

= = = Discovery = = =

In the spring of 2008 , the ORNL started production of californium for a commercial order by an oil company ; Hamilton learned that in the summer , making a deal on subsequent extraction of berkelium . In September 2008 , Oganessian , Hamilton , and Roberto assembled to coordinate planning on the experiment . In November 2008 , the U.S. Department of Energy , the state department oversight over the reactor in Oak Ridge , allowed the scientific use of the extracted berkelium . The production lasted 250 days and ended in late December 2008 , resulting in 22 milligrams of berkelium , enough to perform the experiment . In January 2009 , the berkelium was removed from the reactor ; it was subsequently cooled for 90 days and then chemically purified for another 90 days . Its half @-@ life is only 330 days : after that time , half the berkelium produced would have decayed away . Because of this , the berkelium target had to be quickly transported to Russia ; for the experiment to be viable , it had to begin within six months of its departure from the United States . The target was packed into five lead containers to be sent on a commercial flight from New York to Moscow .

Russian customs officials twice refused to let the target enter the country because of missing or incomplete paperwork . Over the span of a few days , the target traveled over the Atlantic Ocean five times . On its arrival in Russia in early June 2009 , the berkelium was transferred to Research Institute of Atomic Reactors (RIAR) in Dimitrovgrad , Ulyanovsk Oblast , where it was deposited as a 300 @-@ nanometer @-@ thin layer on a titanium film . In July 2009 , it was then transported to Dubna , where it was installed in the particle accelerator at JINR . The calcium @-@ 48 beam was generated by chemically extracting the small quantities of calcium @-@ 48 present in naturally occurring calcium , enriching it 500 times in the closed town of Lesnoy , Sverdlovsk Oblast , Russia .

The experiment began on July 28 , 2009 . In January 2010 , scientists at the Flerov Laboratory of Nuclear Reactions announced internally that they had detected the decay of a new element with atomic number 117 via two decay chains : one of an odd @-@ odd isotope undergoing 6 alpha decays before spontaneous fission , and one of an odd @-@ even isotope undergoing 3 alpha decays before fission . The obtained data from the experiment was sent to the LLNL for further analysis . On April 9 , 2010 , an official report was released in the journal Physical Review Letters identifying the isotopes as 294Uus and 293Uus , which were shown to have half @-@ lives on the order of tens or hundreds of milliseconds . The work was signed by all parties involved in the experiment to some extent : JINR , ORNL , LLNL , RIAR , Vanderbilt , and the University of Nevada (Las Vegas , Nevada , U.S.) , which provided data analysis support . The isotopes were formed as follows :

249
97Bk + 48
20Ca ? 297
117Uus * ? 294
117Uus + 3 1
0n (1 event)
249
97Bk + 48

20Ca ? 297
117Uus * ? 293
117Uus + 4 1
0n (5 events)

= = = Confirmation = = =

All of ununseptium 's daughter isotopes (decay products) were previously unknown ; therefore , their properties could not be used to confirm the claim of discovery . In 2011 , when one of the decay products (ununpentium @-@ 289) was synthesized directly , its properties matched those measured in the claimed indirect synthesis from the decay of ununseptium . The discoverers did not submit a claim for their findings in 2007 ? 2011 when the Joint Working Party was reviewing claims of discoveries of new elements .

The Dubna team repeated the experiment in 2012 , creating seven atoms of ununseptium and confirming their earlier synthesis of ununoctium (produced after some time when a significant quantity of the berkelium @-@ 249 target had beta decayed to californium @-@ 249) . The results of the experiment matched the previous outcome ; the scientists have since filed an application to register the element . In 2014 , a joint German ? American collaboration of scientists from the ORNL and the GSI Helmholtz Center for Heavy Ion Research in Darmstadt , Germany , claimed to have confirmed discovery of the element . The team repeated the Dubna experiment using the Darmstadt accelerator , creating two atoms of ununseptium @-@ 294 .

In December 2015 , the JWP officially recognized the discovery , and thus the listed discoverers ? JINR , LLNL , and ORNL ? were given the right to suggest an official name for the element .

= = = Naming = = =

Using Mendeleev 's nomenclature for unnamed and undiscovered elements , ununseptium should be known as eka @-@ astatine . Using the 1979 IUPAC recommendations , the element should be temporarily called ununseptium (symbol Uus) until the discovery is confirmed and a permanent name chosen ; the temporary name is formed from Latin roots " one " , " one " , and " seven " , a reference to the element 's atomic number of 117 . Many scientists in the field call it " element 117 " , with the symbol (117) or 117 . According to guidelines of the International Union of Pure and Applied Chemistry (IUPAC) valid at the moment of the discovery approval , the permanent names of new elements should have ended in " -ium " ; this included ununseptium , even if the element was a halogen , which traditionally have names ending in " -ine " ; however , the new recommendations published in 2016 recommended using the " -ine " ending for new group 17 elements .

After the original synthesis in 2010 , scientists declared naming was a sensitive question , and it was avoided as far as possible . However , Hamilton declared that year , " I was crucial in getting the group together and in getting the 249Bk target essential for the discovery . As a result of that , I ? m going to get to name the element . I can ? t tell you the name , but it will bring distinction to the region " .

In June 2016 , IUPAC published a declaration stating the discoverers submitted their suggestions for naming the new elements to the IUPAC ; the suggestion for the element 117 was tennessine , with a symbol of Ts , after " the region of Tennessee " . The names are recommended for acceptance by the IUPAC Inorganic Chemistry Division ; formal acceptance should occur after a five @-@ months term expires after the declaration has been published .

= = Predicted properties = =

= = = Nuclear stability and isotopes = = =

The stability of nuclei quickly decreases with the increase in atomic number after curium , element

96 , whose half @-@ life is four orders of magnitude longer than that of any subsequent 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 . Ununseptium is the second @-@ heaviest element created so far , and has a half @-@ life of less than one second ; this is longer than the predicted value used in the discovery report . The Dubna team believes that the synthesis of the element is direct experimental proof of the existence of the island of stability .

It has been calculated that the isotope 295Uus would have a half @-@ life of 18 ± 7 milliseconds and that it may be possible to produce this isotope via the same berkelium ? calcium reaction used in the discoveries of the known isotopes , 293Uus and 294Uus . The chance of this reaction producing 295Uus is estimated to be , at most , one @-@ seventh the chance of producing 294Uus . Calculations using a quantum tunneling model predict the existence of several isotopes of ununseptium up to 303Uus . The most stable of these is expected to be 296Uus with an alpha @-@ decay half @-@ life of 40 milliseconds . A liquid drop model study on the element 's isotopes shows similar results ; it suggests a general trend of increasing stability for isotopes heavier than 301Uus , with partial half @-@ lives exceeding the age of the universe for the heaviest isotopes like 335Uus when beta decay is not considered .

= = = Atomic and physical = = =

Ununseptium is expected to be a member of group 17 in the periodic table , below the five halogens ; fluorine , chlorine , bromine , iodine , and astatine , each of which has seven valence electrons with a configuration of ns2np5 . For ununseptium , being in the seventh period (row) of the periodic table , continuing the trend would predict a valence electron configuration of 7s27p5 , and it would therefore be expected to behave similarly to the halogens in many respects that relate to this electronic state .

Significant differences are likely to arise , largely due to spin ? orbit interaction ? the mutual interaction between the motion and spin of electrons . The spin ? orbit 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 ununseptium atoms , this lowers the 7s and the 7p electron energy levels , stabilizing the corresponding electrons , although two of the 7p electron energy levels are more stabilized than the other four . The stabilization of the 7s electrons is called the inert pair effect ; the effect that separates the 7p subshell into the more @-@ stabilized and the less @-@ stabilized parts is called subshell splitting . 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 . For many theoretical purposes , the valence electron configuration may be represented to reflect the 7p subshell split as 7s27p2
1 / 27p3
3 / 2 .

Differences for other electron levels also exist . For example , the 6d electron levels (also split in two , with four being 6d3 / 2 and six being 6d5 / 2) are both raised , so they are close in energy to the 7s ones , although no 6d electron chemistry has been predicted for ununseptium . The difference between the 7p1 / 2 and 7p3 / 2 levels is abnormally high ; 9 @.@ 8 eV . Astatine 's 6p subshell split is only 3 @.@ 8 eV , and its 6p1 / 2 chemistry has already been called " limited " . These effects cause ununseptium 's chemistry to differ from those of its upper neighbors (see below) .

Ununseptium 's first ionization energy ? the energy required to remove an electron from a neutral atom ? is predicted to be 7 @.@ 7 eV , lower than those of the halogens , again following the trend .

Like its neighbors in the periodic table , ununseptium is expected to have the lowest electron affinity ? energy released when an electron is added to the atom ? in its group ; 2 @.@ 6 or 1 @.@ 8 eV . The electron of the hypothetical hydrogen @-@ like ununseptium atom ? oxidized so it has only one electron , Uus116 + ? is predicted to move so quickly that its mass is 1 @.@ 9 times that of a non @-@ moving electron , a feature attributable to relativistic effects . For comparison , the figure for hydrogen @-@ like astatine is 1 @.@ 27 and the figure for hydrogen @-@ like iodine is 1 @.@ 08 . Simple extrapolations of relativity laws indicate a contraction of atomic radius . Advanced calculations show that the radius of an ununseptium atom that has formed one covalent bond would be 165 pm , while that of astatine would be 147 pm . With the seven outermost electrons removed , ununseptium is finally smaller ; 57 pm for ununseptium and 61 pm for astatine .

The melting and boiling points of ununseptium are not known ; earlier papers predicted about 350 ? 500 ° C and 550 ° C respectively , or 350 ? 550 ° C and 610 ° C respectively . These values exceed those of astatine and the lighter halogens , following periodic trends . A later paper predicts the boiling point of ununseptium to be 345 ° C (that of astatine is estimated as 309 ° C , 337 ° C , or 370 ° C , although experimental values of 230 ° C and 411 ° C have been reported) . The density of ununseptium is expected to be between 7 @.@ 1 and 7 @.@ 3 g · cm ? 3 , continuing the trend of increasing density among the halogens ; that of astatine is estimated to be between 6 @.@ 2 and 6 @.@ 5 g · cm ? 3 .

= = = Chemical = = =

Unlike the previous group 17 elements , ununseptium may not exhibit chemical behavior common to the halogens . For example , extant members of the group routinely accept an electron to achieve the more stable electronic configuration of a noble gas , one having eight electrons (octet) in its valence shell This ability weakens as atomic weight increases going down the group ; ununseptium would be the least willing to accept an electron . Of the oxidation states it is predicted to form , ? 1 is expected to be the least common .

There is another opportunity for ununseptium to complete its octet ? by forming a covalent bond . Like the halogens , when two ununseptium atoms meet they are expected to form a Uus ? Uus bond to give a diatomic molecule . Such molecules are commonly bound via single sigma bonds between the atoms ; these are different from pi bonds , which are divided into two parts , each shifted in a direction perpendicular to the line between the atoms , and opposite one another rather than being located directly between the atoms they bind . Sigma bonding has been calculated to show a great antibonding character in the At2 molecule and is not as favorable energetically . Ununseptium is predicted to continue the trend ; a strong pi character should be seen in the bonding of Uus2 . The molecule UusCl is predicted to go further , being bonded with a single pi bond .

Aside from the unstable ? 1 state , three more oxidation states are predicted ; + 5 , + 3 , and + 1 . The + 1 state should be especially stable because of the destabilization of the three outermost 7p3 / 2 electrons , forming a stable , half @-@ filled subshell configuration ; astatine shows similar effects . The + 3 state should be important , again due to the destabilized 7p3 / 2 electrons . The + 5 state is predicted to be uncommon because the 7p1 / 2 electrons are oppositely stabilized . The + 7 state has not been shown ? even computationally ? to be achievable . Because the 7s electrons are greatly stabilized , it has been hypothesized that ununseptium effectively has only five valence electrons .

The simplest possible ununseptium compound would be the monohydride , UusH . The bonding is expected to be provided by a 7p3 / 2 electron of ununseptium and the 1s electron of hydrogen . The non @-@ bonding nature of the 7p1 / 2 spinor is because ununseptium is expected not to form purely sigma or pi bonds . Therefore , the destabilized (thus expanded) 7p3 / 2 spinor is responsible for bonding . This effect lengthens the UusH molecule by 17 picometers compared with the overall length of 195 pm . Since the ununseptium p electron bonds are two @-@ thirds sigma , the bond is only two @-@ thirds as strong as it would be if ununseptium featured no spin ? orbit interactions . The molecule thus follows the trend for halogen hydrides , showing an increase in bond length and a decrease in dissociation energy compared to AtH . The molecules TlUus and

UutUus may be viewed analogously , taking into account an opposite effect shown by the fact that the element 's p1 / 2 electrons are stabilized . These two characteristics result in a relatively small dipole moment (product of difference between electric charges of atoms and displacement of the atoms) for TlUus ; only 1 @.@ 67 D , the positive value implying that the negative charge is on the ununseptium atom . For UutUus , the strength of the effects are predicted to cause a transfer of the electron from the ununseptium atom to the ununtrium atom , with the dipole moment value being ? 1 @.@ 80 D. The spin ? orbit interaction increases the dissociation energy of the UusF molecule because it lowers the electronegativity of ununseptium , causing the bond with the extremely electronegative fluorine atom to have a more ionic character . Ununseptium monofluoride should feature the strongest bonding of all group 17 element monofluorides .

VSEPR theory predicts a bent @-@ T @-@ shaped molecular geometry for the group 17 trifluorides . All known halogen trifluorides have this molecular geometry and have a structure of AX3E2 ? a central atom , denoted A , surrounded by three ligands , X , and two unshared electron pairs , E. If relativistic effects are ignored , UusF3 should follow its lighter congeners in having a bent @-@ T @-@ shaped molecular geometry . More sophisticated predictions show that this molecular geometry would not be energetically favored for UusF3 , predicting instead a trigonal planar molecular geometry (AX3E0) . This shows that VSEPR theory may not be consistent for the superheavy elements . The UusF3 molecule is predicted to be significantly stabilized by spin ? orbit interactions ; a possible rationale may be the large difference in electronegativity between ununseptium and fluorine , giving the bond a partially ionic character .