= Francium =

Francium is a chemical element with symbol Fr and atomic number 87 . It used to be known as eka @-@ caesium and actinium K. It is the second @-@ least electronegative element , behind only caesium . Francium is a highly radioactive metal that decays into astatine , radium , and radon . As an alkali metal , it has one valence electron .

Bulk francium has never been viewed . Because of the general appearance of the other elements in its periodic table column , it is assumed that francium would appear as a highly reflective metal , if enough could be collected together to be viewed as a bulk solid or liquid . Obtaining such a sample is highly improbable , since the extreme heat of decay (the half @-@ life of its longest @-@ lived isotope is only 22 minutes) would immediately vaporize any viewable quantity of the element .

Francium was discovered by Marguerite Perey in France (from which the element takes its name) in 1939 . It was the last element first discovered in nature , rather than by synthesis . Outside the laboratory , francium is extremely rare , with trace amounts found in uranium and thorium ores , where the isotope francium @-@ 223 continually forms and decays . As little as 20 ? 30 g (one ounce) exists at any given time throughout the Earth 's crust ; the other isotopes (except for francium @-@ 221) are entirely synthetic . The largest amount produced in the laboratory was a cluster of more than 300 @,@ 000 atoms .

= = Characteristics = =

Francium is the most unstable of the naturally occurring elements : its most stable isotope , francium @-@ 223 , has a half @-@ life of only 22 minutes . In contrast , astatine , the second @-@ least stable naturally occurring element , has a half @-@ life of 8 @.@ 5 hours . All isotopes of francium decay into astatine , radium , or radon . Francium is also less stable than all synthetic elements up to element 105 , dubnium .

Francium is an alkali metal whose chemical properties mostly resemble those of caesium . A heavy element with a single valence electron , it has the highest equivalent weight of any element . Liquid francium ? if created ? should have a surface tension of 0 @.@ 05092 N / m at its melting point . Francium 's melting point was calculated to be around 27 ° C (80 ° F , 300 K) . The melting point is uncertain because of the element 's extreme rarity and radioactivity . Thus , the estimated boiling point value of 677 ° C (1250 ° F , 950 K) is also uncertain .

Linus Pauling estimated the electronegativity of francium at 0 @.@ 7 on the Pauling scale , the same as caesium ; the value for caesium has since been refined to 0 @.@ 79 , but there are no experimental data to allow a refinement of the value for francium . Francium has a slightly higher ionization energy than caesium , 392 @.@ 811 (4) kJ / mol as opposed to 375 @.@ 7041 (2) kJ / mol for caesium , as would be expected from relativistic effects , and this would imply that caesium is the less electronegative of the two . Francium should also have a higher electron affinity than caesium and the Fr ? ion should be more polarizable than the Cs ? ion . The CsFr molecule is predicted to have francium at the negative end of the dipole , unlike all known heterodiatomic alkali metal molecules . Francium superoxide (FrO2) is expected to have a more covalent character than its lighter congeners ; this is attributed to the 6p electrons in francium being more involved in the francium ? oxygen bonding .

Francium coprecipitates with several caesium salts , such as caesium perchlorate , which results in small amounts of francium perchlorate . This coprecipitation can be used to isolate francium , by adapting the radiocaesium coprecipitation method of Glendenin and Nelson . It will additionally coprecipitate with many other caesium salts , including the iodate , the picrate , the tartrate (also rubidium tartrate) , the chloroplatinate , and the silicotungstate . It also coprecipitates with silicotungstic acid , and with perchloric acid , without another alkali metal as a carrier , which provides other methods of separation . Nearly all francium salts are water @-@ soluble .

= = Isotopes = =

There are 34 known isotopes of francium ranging in atomic mass from 199 to 232 . Francium has seven metastable nuclear isomers . Francium @-@ 223 and francium @-@ 221 are the only isotopes that occur in nature , though the former is far more common .

Francium @-@ 223 is the most stable isotope , with a half @-@ life of 21 @.@ 8 minutes , and it is highly unlikely that an isotope of francium with a longer half @-@ life will ever be discovered or synthesized . Francium @-@ 223 is the fifth product of the actinium decay series as the daughter isotope of actinium @-@ 227 . Francium @-@ 223 then decays into radium @-@ 223 by beta decay (1149 keV decay energy) , with a minor (0 @.@ 006 %) alpha decay path to astatine @-@ 219 (5 @.@ 4 MeV decay energy) .

Francium @-@ 221 has a half @-@ life of 4 @.@ 8 minutes . It is the ninth product of the neptunium decay series as a daughter isotope of actinium @-@ 225 . Francium @-@ 221 then decays into astatine @-@ 217 by alpha decay (6 @.@ 457 MeV decay energy) .

The least stable ground state isotope is francium @-@ 215 , with a half @-@ life of 0 @.@ 12 ?s . (9 @.@ 54 MeV alpha decay to astatine @-@ 211) : Its metastable isomer , francium @-@ 215m , is less stable still , with a half @-@ life of only 3 @.@ 5 ns .

= = Applications = =

Due to its instability and rarity , there are no commercial applications for francium . It has been used for research purposes in the fields of chemistry and of atomic structure . Its use as a potential diagnostic aid for various cancers has also been explored , but this application has been deemed impractical .

Francium 's ability to be synthesized , trapped , and cooled , along with its relatively simple atomic structure have made it the subject of specialized spectroscopy experiments . These experiments have led to more specific information regarding energy levels and the coupling constants between subatomic particles . Studies on the light emitted by laser @-@ trapped francium @-@ 210 ions have provided accurate data on transitions between atomic energy levels which are fairly similar to those predicted by quantum theory .

= = History = =

As early as 1870 , chemists thought that there should be an alkali metal beyond caesium , with an atomic number of 87 . It was then referred to by the provisional name eka @-@ caesium . Research teams attempted to locate and isolate this missing element , and at least four false claims were made that the element had been found before an authentic discovery was made .

= = = Erroneous and incomplete discoveries = = =

Soviet chemist D. K. Dobroserdov was the first scientist to claim to have found eka @-@ caesium , or francium . In 1925 , he observed weak radioactivity in a sample of potassium , another alkali metal , and incorrectly concluded that eka @-@ caesium was contaminating the sample (the radioactivity from the sample was from the naturally occurring potassium radioisotope , potassium @-@ 40) . He then published a thesis on his predictions of the properties of eka @-@ caesium , in which he named the element russium after his home country . Shortly thereafter , Dobroserdov began to focus on his teaching career at the Polytechnic Institute of Odessa , and he did not pursue the element further .

The following year , English chemists Gerald J. F. Druce and Frederick H. Loring analyzed X @-@ ray photographs of manganese (II) sulfate . They observed spectral lines which they presumed to be of eka @-@ caesium . They announced their discovery of element 87 and proposed the name alkalinium , as it would be the heaviest alkali metal .

In 1930 , Fred Allison of the Alabama Polytechnic Institute claimed to have discovered element 87 when analyzing pollucite and lepidolite using his magneto @-@ optical machine . Allison requested that it be named virginium after his home state of Virginia , along with the symbols Vi and Vm . In

1934 , H.G. MacPherson of UC Berkeley disproved the effectiveness of Allison 's device and the validity of this false discovery .

In 1936 , Romanian physicist Horia Hulubei and his French colleague Yvette Cauchois also analyzed pollucite , this time using their high @-@ resolution X @-@ ray apparatus . They observed several weak emission lines , which they presumed to be those of element 87 . Hulubei and Cauchois reported their discovery and proposed the name moldavium , along with the symbol Ml , after Moldavia , the Romanian province where Hulubei was born . In 1937 , Hulubei 's work was criticized by American physicist F. H. Hirsh Jr . , who rejected Hulubei 's research methods . Hirsh was certain that eka @-@ caesium would not be found in nature , and that Hulubei had instead observed mercury or bismuth X @-@ ray lines . Hulubei insisted that his X @-@ ray apparatus and methods were too accurate to make such a mistake . Because of this , Jean Baptiste Perrin , Nobel Prize winner and Hulubei 's mentor , endorsed moldavium as the true eka @-@ caesium over Marguerite Perey 's recently discovered francium . Perey took pains to be accurate and detailed in her criticism of Hulubei 's work , and finally she was credited as the sole discoverer of element 87 . All other previous purported discoveries of element 87 were ruled out due to francium 's very limited half @-@ life .

= = = Perey 's analysis = = =

Eka @-@ caesium was discovered in 1939 by Marguerite Perey of the Curie Institute in Paris , when she purified a sample of actinium @-@ 227 which had been reported to have a decay energy of 220 keV . Perey noticed decay particles with an energy level below 80 keV . Perey thought this decay activity might have been caused by a previously unidentified decay product , one which was separated during purification , but emerged again out of the pure actinium @-@ 227 . Various tests eliminated the possibility of the unknown element being thorium , radium , lead , bismuth , or thallium . The new product exhibited chemical properties of an alkali metal (such as coprecipitating with caesium salts) , which led Perey to believe that it was element 87 , caused by the alpha decay of actinium @-@ 227 . Perey then attempted to determine the proportion of beta decay to alpha decay in actinium @-@ 227 . Her first test put the alpha branching at 0 @.@ 6 % , a figure which she later revised to 1 % .

Perey named the new isotope actinium @-@ K (it is now referred to as francium @-@ 223) and in 1946 , she proposed the name catium for her newly discovered element , as she believed it to be the most electropositive cation of the elements . Irène Joliot @-@ Curie , one of Perey 's supervisors , opposed the name due to its connotation of cat rather than cation . Perey then suggested francium , after France . This name was officially adopted by the International Union of Pure and Applied Chemistry in 1949 , becoming the second element after gallium to be named after France . It was assigned the symbol Fa , but this abbreviation was revised to the current Fr shortly thereafter . Francium was the last element discovered in nature , rather than synthesized , following rhenium in 1925 . Further research into francium 's structure was carried out by , among others , Sylvain Lieberman and his team at CERN in the 1970s and 1980s .

= = Occurrence = =

= = = Natural = = =

223Fr is the result of the alpha decay of 227Ac and can be found in trace amounts in uranium and thorium minerals . In a given sample of uranium , there is estimated to be only one francium atom for every 1 × 1018 uranium atoms . It is also calculated that there is at most 30 g of francium in the Earth 's crust at any given time .

= = = Synthesis = = =

Francium can be synthesized in the nuclear reaction :
197Au + 18O ? 210Fr + 5 n
This process , developed by Stony Brook Physics , yields francium isotopes with masses of 209 , 210 , and 211 , which are then isolated by the magneto @-@ optical trap (MOT) . The production rate of a particular isotope depends on the energy of the oxygen beam . An 18O beam from the Stony Brook LINAC creates 210Fr in the gold target with the nuclear reaction 197Au + 18O ? 210Fr + 5n . The production required some time to develop and understand . It was critical to operate the gold target very close to its melting point and to make sure that its surface was very clean . The nuclear reaction embeds the francium atoms deep in the gold target , and they must be removed efficiently . The atoms quickly diffuse to the surface of the gold target and are released as ions , but this does not happen every time . The francium ions are guided by electrostatic lenses until they land in a surface of hot yttrium and become neutral again . The francium is then injected into a glass bulb . A magnetic field and laser beams cool and confine the atoms . Although the atoms remain in the trap for only about 20 seconds before escaping (or decaying) , a steady stream of fresh atoms replaces those lost , keeping the number of trapped atoms roughly constant for minutes or longer . Initially , about 1000 francium atoms were trapped in the experiment . This was gradually improved and the setup is capable of trapping over 300 @,@ 000 neutral atoms of francium a time . These are neutral metallic atoms in a gaseous unconsolidated state . Enough francium is trapped that a video camera can capture the light given off by the atoms as they fluoresce . The atoms appear as a glowing sphere about 1 millimeter in diameter . This was the first time that anyone had ever seen francium . The researchers can now make extremely sensitive measurements of the light emitted and absorbed by the trapped atoms , providing the first experimental results on various transitions between atomic energy levels in francium . Initial measurements show very good agreement between experimental values and calculations based on quantum theory . Other synthesis methods include bombarding radium with neutrons , and bombarding thorium with protons , deuterons , or helium ions . Francium has not been synthesized in amounts large enough to weigh .