= 20 @.@ 07 (7) hours) as this isotope can be easily isolated as required as the decay product of 255Es (t1 / 2 =
39 @.@ 8 (12) days) .

= = Synthesis in nuclear explosions = =

The analysis of the debris at the 10 @-@ megaton Ivy Mike nuclear test was a part of long @-@ term project , one of the goals of which was studying the efficiency of production of transuranium elements in high @-@ power nuclear explosions . The motivation for these experiments was as follows : synthesis of such elements from uranium requires multiple neutron capture . The probability of such events increases with the neutron flux , and nuclear explosions are the most powerful neutron sources , providing densities of the order 1023 neutrons / cm2 within a microsecond , i.e. about 1029 neutrons / (cm2 · s) . In comparison , the flux of the HFIR reactor is 5 × 1015 neutrons / (cm2 · s) . A dedicated laboratory was set up right at Enewetak Atoll for preliminary analysis of debris , as some isotopes could have decayed by the time the debris samples reached the U.S. The laboratory was receiving samples for analysis , as soon as possible , from airplanes equipped with paper filters which flew over the atoll after the tests . Whereas it was hoped to discover new chemical elements heavier than fermium , those were not found after a series of megaton explosions conducted between 1954 and 1956 at the atoll .
The atmospheric results were supplemented by the underground test data accumulated in the 1960s at the Nevada Test Site , as it was hoped that powerful explosions conducted in confined space might result in improved yields and heavier isotopes . Apart from traditional uranium charges , combinations of uranium with americium and thorium have been tried , as well as a mixed plutonium @-@ neptunium charge . They were less successful in terms of yield that was attributed to stronger losses of heavy isotopes due to enhanced fission rates in heavy @-@ element charges . Isolation of the products was found to be rather problematic , as the explosions were spreading debris through melting and vaporizing rocks under the great depth of 300 ? 600 meters , and drilling to such depth in order to extract the products was both slow and inefficient in terms of collected volumes .
Among the nine underground tests , which were carried between 1962 and 1969 and codenamed Anacostia (5 @.@ 2 kilotons , 1962) , Kennebec (< 5 kilotons , 1963) , Par (38 , kilotons , 1964) , Barbel (< 20 kilotons , 1964) , Tweed (< 20 kilotons , 1965) , Cyclamen (13 kilotons , 1966) , Kankakee (20 @-@ 200 kilotons , 1966) , Vulcan (25 kilotons , 1966) and Hutch (20 @-@ 200 kilotons , 1969) , the last one was most powerful and had the highest yield of transuranium elements . In the dependence on the atomic mass number , the yield showed a saw @-@ tooth behavior with the lower values for odd isotopes , due to their higher fission rates . The major practical problem of the entire proposal was however collecting the radioactive debris dispersed by the powerful blast . Aircraft filters adsorbed only about 4 × 10 ? 14 of the total amount and collection of tons of corals at Enewetak Atoll increased this fraction by only two orders of magnitude . Extraction of about 500 kilograms of underground rocks 60 days after the Hutch explosion recovered only about 10 ? 7 of the total charge . The amount of transuranium elements in this 500 @-@ kg batch was only 30 times higher than in a 0 @.@ 4 kg rock picked up 7 days after the test . This observation demonstrated the highly nonlinear dependence of the transuranium elements yield on the amount of retrieved radioactive rock . In order to accelerate sample collection after explosion , shafts were drilled at the site not after but before the test , so that explosion would expel radioactive material from the epicenter , through the shafts , to collecting volumes near the surface . This method was tried in the Anacostia and Kennebec tests and instantly provided hundreds kilograms of material , but with actinide concentration 3 times lower than in samples obtained after drilling ; whereas such method could have been efficient in scientific studies of short @-@ lived isotopes , it could not improve the overall collection efficiency of the produced actinides .
Although no new elements (apart from einsteinium and fermium) could be detected in the nuclear test debris , and the total yields of transuranium elements were disappointingly low , these tests did provide significantly higher amounts of rare heavy isotopes than previously available in laboratories . So 6 × 109 atoms of 257Fm could be recovered after the Hutch detonation . They were then used in

the studies of thermal @-@ neutron induced fission of 257Fm and in discovery of a new fermium isotope 258Fm . Also , the rare 250Cm isotope was synthesized in large quantities , which is very difficult to produce in nuclear reactors from its progenitor 249Cm ? the half @-@ life of 249Cm (64 minutes) is much too short for months @-@ long reactor irradiations , but is very " long " on the explosion timescale .

= = Natural occurrence = =

 Because of the short half @-@ life of all isotopes of fermium , any primordial fermium , that is fermium that could be present on the Earth during its formation , has decayed by now . Synthesis of fermium from naturally occurring actinides uranium and thorium in the Earth crust requires multiple neutron capture , which is an extremely unlikely event . Therefore , most fermium is produced on Earth in scientific laboratories , high @-@ power nuclear reactors , or in nuclear weapons tests , and is present only within a few months from the time of the synthesis . The transuranic elements from americium to fermium did occur naturally in the natural nuclear fission reactor at Oklo , but no longer do so .

= = Chemistry = =

 The chemistry of fermium has only been studied in solution using tracer techniques , and no solid compounds have been prepared . Under normal conditions , fermium exists in solution as the Fm3 + ion , which has a hydration number of 16 @.@ 9 and an acid dissociation constant of 1 @.@ 6 × 10 ? 4 (pKa = 3 @.@ 8) . Fm3 + forms complexes with a wide variety of organic ligands with hard donor atoms such as oxygen , and these complexes are usually more stable than those of the preceding actinides . It also forms anionic complexes with ligands such as chloride or nitrate and , again , these complexes appear to be more stable than those formed by einsteinium or californium . It is believed that the bonding in the complexes of the later actinides is mostly ionic in character : the Fm3 + ion is expected to be smaller than the preceding An3 + ions because of the higher effective nuclear charge of fermium , and hence fermium would be expected to form shorter and stronger metal ? ligand bonds .
 Fermium (III) can be fairly easily reduced to fermium (II) , for example with samarium (II) chloride , with which fermium coprecipitates . The electrode potential has been estimated to be similar to that of the ytterbium (III) / (II) couple , or about ? 1 @.@ 15 V with respect to the standard hydrogen electrode , a value which agrees with theoretical calculations . The Fm2 + / Fm0 couple has an electrode potential of ? 2 @.@ 37 (10) V based on polarographic measurements .

= = Toxicity = =

 Although few people come in contact with fermium , the International Commission on Radiological Protection has set annual exposure limits for the two most stable isotopes . For fermium @-@ 253 , the ingestion limit was set at 107 becquerels (1 Bq is equivalent to one decay per second) , and the inhalation limit at 105 Bq ; for fermium @-@ 257 , at 105 Bq and 4000 Bq respectively .