Meitnerium

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Meitnerium is a chemical element with symbol **Mt** and atomic number 109. It is an extremely radioactive synthetic element (an element not found in nature that can be created in a laboratory). The most stable known isotope, meitnerium-278, has a half-life of 7.6 seconds. The GSI Helmholtz Centre for Heavy Ion Research near Darmstadt, Germany, first created this element in 1982. It is named for Lise Meitner.

In the periodic table, meitnerium is a d-block transactinide element. It is a member of the 7th period and is placed in the group 9 elements, although no chemical experiments have yet been carried out to confirm that it behaves as the heavier homologue to iridium in group 9 as the seventh member of the 6d series of transition metals. Meitnerium is calculated to have similar properties to its lighter homologues, cobalt, rhodium, and iridium.

Meitnerium, $_{109}$Mt

General properties	
Name, symbol	meitnerium, Mt
Meitnerium in the periodic table	
Atomic number (*Z*)	109
Group, block	group 9, d-block
Period	period 7
Element category	unknown, but probably a transition metal[3][4]
Standard atomic weight (A_r)	[278]
Electron configuration	[Rn] $5f^{14}$ $6d^7$ $7s^2$ *(calculated)*[3][5]
per shell	2, 8, 18, 32, 32, 15, 2 *(predicted)*
Physical properties	
Phase	solid *(predicted)*[4]
Density near r.t.	37.4 g/cm^3 *(predicted)*[3]
Atomic properties	
Oxidation states	9, 8, **6**, 4, **3**, **1** *(predicted)*[3][6][7][8]
Ionization energies	1st: 800.8 kJ/mol 2nd: 1823.6 kJ/mol 3rd: 2904.2 kJ/mol

Isotopes

Meitnerium has no stable or naturally occurring isotopes. Several radioactive isotopes have been synthesized in the laboratory, either by fusing two atoms or by observing the decay of heavier elements. Eight different isotopes of meitnerium have been reported with atomic masses 266, 268, 270, and 274–278, two of which, meitnerium-268 and meitnerium-270, have known but unconfirmed metastable states. Most of these decay predominantly through alpha decay, although some undergo spontaneous fission.[23]

Stability and half-lives

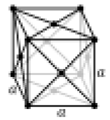
All meitnerium isotopes are extremely unstable and radioactive; in general, heavier isotopes are more stable than the lighter. The most stable known meitnerium isotope, ^{278}Mt, is also the heaviest known; it has a half-life of 7.6 seconds. A metastable nuclear isomer, ^{270m}Mt, has been reported to also have a half-life of over a second. The isotopes ^{276}Mt and ^{274}Mt have half-lives of 0.72 and 0.44 seconds respectively. The remaining four isotopes have half-lives between 1 and 20 milliseconds.[23] The undiscovered isotope ^{281}Mt has been predicted to be the most stable towards beta decay;[24] no known meitnerium isotope has been observed to undergo beta decay.[23] Some unknown isotopes, such as ^{265}Mt, ^{272}Mt, ^{273}Mt, and ^{279}Mt, are predicted to have half-lives longer than the known isotopes.[23][25] Before its discovery, ^{274}Mt and ^{277}Mt were predicted to have half-lives of 20 seconds and 1 minute respectively, but they were later found to have half-lives of only 0.44 seconds and 5 milliseconds respectively.[23]

Predicted properties

Chemical

Meitnerium is the seventh member of the 6d series of transition metals. Since element 112 (copernicium) has been shown to be a transition metal, it is expected that all the elements from 104 to 112 would form a fourth transition metal series, with meitnerium as part of the platinum group metals.[19] Calculations on its ionization potentials and atomic and ionic radii are similar to that of its lighter homologue iridium, thus implying that meitnerium's basic properties will resemble those of the other group 9 elements, cobalt, rhodium, and iridium.[3]

Prediction of the probable chemical properties of meitnerium has not received much attention recently. Meitnerium is expected to be a noble metal. Based on the most stable oxidation states of the lighter group 9 elements, the most stable oxidation states of meitnerium are predicted to be the +6, +3, and +1 states, with the +3 state being the most stable in aqueous solutions. In comparison, rhodium and iridium show a maximum oxidation state of +6, while the most stable states are +4 and +3 for iridium and +3 for rhodium.[3] The oxidation state +9, represented only by iridium in $[IrO_4]^+$, might be possible for its congener meitnerium in the nonafluoride (MtF_9) and the $[MtO_4]^+$ cation, although $[IrO_4]^+$ is expected to be more stable.[7] The tetrahalides of meitnerium have also been predicted to have similar stabilities to those of iridium, thus also allowing a stable +4 state.[6] It is further expected that the maximum oxidation states of elements from bohrium (element 107) to darmstadtium (element 110) may be stable in the gas phase but not in aqueous solution.[3]

	(more) *(all estimated)*[3]
Atomic radius	empirical: 128 pm *(predicted)*[3][8]
Covalent radius	129 pm *(estimated)*[9]
Miscellanea	
Crystal structure	face-centered cubic (fcc) *(predicted)*[4] 
Magnetic ordering	paramagnetic *(predicted)*[10]
CAS Number	54038-01-6
History	
Naming	after Lise Meitner
Discovery	Gesellschaft für Schwerionenforschung (1982)

Most stable isotopes of meitnerium

iso	NA	half-life	DM	DE (MeV)	DP
^{278}Mt	syn	7.6 s	α	9.6	^{274}Bh
^{276}Mt	syn	0.72 s	α	9.71	^{272}Bh
^{274}Mt	syn	0.44 s	α	9.76	^{270}Bh
^{270m}Mt ?	syn	1.1 s	α		^{266}Bh

Physical and atomic

Meitnerium is expected to be a solid under normal conditions and assume a face-centered cubic crystal structure, similarly to its lighter congener iridium.[4] It should be a very heavy metal with a density of around 37.4 g/cm^3, which would be the second-highest of any of the 118 known elements, second only to that predicted for its neighbor hassium (41 g/cm^3). In comparison, the densest known element that has had its density measured, osmium, has a density of only 22.61 g/cm^3. This results from meitnerium's high atomic weight, the lanthanide and actinide contractions, and relativistic effects, although production of enough meitnerium to measure this quantity would be impractical, and the sample would quickly decay.[3] Meitnerium is also predicted to be paramagnetic.[10]

Theoreticians have predicted the covalent radius of meitnerium to be 6 to 10 pm larger than that of iridium.[31] For example, the Mt–O bond distance is expected to be around 1.9 Å.[32] The atomic radius of meitnerium is expected to be around 128 pm.[8]

Experimental chemistry

Meitnerium is the first element on the periodic table whose chemistry has not yet been investigated. Unambiguous determination of the chemical characteristics of meitnerium has yet to have been established[33][34] due to the short half-lives of meitnerium isotopes[3] and a limited number of likely volatile compounds that could be studied on a very small scale. One of the few meitnerium compounds that are likely to be sufficiently volatile is meitnerium hexafluoride (MtF_6), as its lighter homologue iridium hexafluoride (IrF_6) is volatile above 60 °C and therefore the analogous compound of meitnerium might also be sufficiently volatile;[19] a volatile octafluoride (MtF_8) might also be possible.[3] For chemical studies to be carried out on a transactinide, at least four atoms must be produced, the half-life of the isotope used must be at least 1 second, and the rate of production must be at least one atom per week.[19] Even though the half-life of ^{278}Mt, the most stable known meitnerium isotope, is 7.6 seconds, long enough to perform chemical studies, another obstacle is the need to increase the rate of production of meitnerium isotopes and allow experiments to carry on for weeks or months so that statistically significant results can be obtained. Separation and detection must be carried out continuously to separate out the meitnerium isotopes and automated systems can then experiment on the gas-phase and solution chemistry of meitnerium as the yields for heavier elements are predicted to be smaller than those for lighter elements; some of the separation techniques used for bohrium and hassium could be reused. However, the experimental chemistry of meitnerium has not received as much attention as that of the heavier elements from copernicium to livermorium.[3][33][35]

The Lawrence Berkeley National Laboratory attempted to synthesize the isotope ^{271}Mt in 2002–2003 for a possible chemical investigation of meitnerium because it was expected that it might be more stable than the isotopes around it as it has 162 neutrons, a magic number for deformed nuclei; its half-life was predicted to be a few seconds, long enough for a chemical investigation.[3][36] However, no atoms of ^{271}Mt were detected,[37] and this isotope of meitnerium is currently unknown.[23]

An experiment determining the chemical properties of a transactinide would need to compare a compound of that transactinide with analogous compounds of some of its lighter homologues:[3] for example, in the chemical characterization of hassium, hassium tetroxide (HsO_4) was compared with the analogous osmium compound, osmium tetroxide (OsO_4).[38] In a preliminary step towards determining the chemical properties of meitnerium, the GSI attempted sublimation of the rhodium compounds rhodium(III) oxide (Rh_2O_3) and rhodium(III) chloride ($RhCl_3$). However, macroscopic amounts of the oxide would not sublimate until 1000 °C and the chloride would not until 780 °C, and then only in the presence of carbon aerosol particles: these temperatures are far too high for such procedures to be used on meitnerium, as most of the current methods used for the investigation of the chemistry of superheavy elements do not work above 500 °C.[34]

Source

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