

# Mendelevium

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**Mendelevium** is a synthetic element with chemical symbol **Md** (formerly **Mv**) and atomic number 101. A metallic radioactive transuranic element in the actinide series, it is the first element that currently cannot be produced in macroscopic quantities through neutron bombardment of lighter elements. It is the third-to-last actinide and the ninth transuranic element. It can only be produced in particle accelerators by bombarding lighter elements with charged particles. A total of sixteen mendelevium isotopes are known, the most stable being <sup>258</sup>Md with a half-life of 51 days; nevertheless, the shorter-lived <sup>256</sup>Md (half-life 1.17 hours) is most commonly used in chemistry because it can be produced on a larger scale.

Mendelevium was discovered by bombarding einsteinium with alpha particles in 1955, the same method still used to produce it today. It was named after Dmitri Mendeleev, father of the periodic table of the chemical elements. Using available microgram quantities of the isotope einsteinium-253, over a million mendelevium atoms may be produced each hour. The chemistry of mendelevium is typical for the late actinides, with a preponderance of the +3 oxidation state but also an accessible +2 oxidation state. Owing to the small amounts of produced mendelevium and all of its isotopes having relatively short half-lives, there are currently no uses for it outside of basic scientific research.

## Characteristics

### Physical

In the periodic table, mendelevium is located to the right of the actinide fermium, to the left of the actinide nobelium, and below the lanthanide thulium. Mendelevium metal has not yet been prepared in bulk quantities, and bulk preparation is currently impossible.<sup>[11]</sup> Nevertheless, a number of predictions and some preliminary experimental results have been done regarding its properties.<sup>[11]</sup>

## Mendelevium, 101Md

### General properties

**Name, symbol** mendelevium, Md

### Mendelevium in the periodic table

**Atomic number** (*Z*) 101

**Group, block** group n/a, f-block

**Period** period 7

**Element category** ☐ actinide

**Standard atomic weight** (*A*<sub>r</sub>) (258)

**Electron configuration** [Rn] 5f<sup>13</sup> 7s<sup>2</sup>  
per shell 2, 8, 18, 32, 31, 8, 2

### Physical properties

**Phase** solid (*predicted*)

**Melting point** 1100 K (827 °C, 1521 °F) (*predicted*)

**Density** near r.t. 10.3(7) g/cm<sup>3</sup> (*predicted*)<sup>[11]</sup>

### Atomic properties

**Oxidation states** 2, 3

**Electronegativity** Pauling scale: 1.3

**Ionization energies** 1st: 635 kJ/mol (estimated)

The lanthanides and actinides, in the metallic state, can exist as either divalent (such as europium and ytterbium) or trivalent (most other lanthanides) metals. The former have  $f^n d^1 s^2$  configurations, whereas the latter have  $f^{n+1} s^2$  configurations. In 1975, Johansson and Rosengren examined the measured and predicted values for the cohesive energies (enthalpies of crystallization) of the metallic lanthanides and actinides, both as divalent and trivalent metals.<sup>[12][13]</sup> The conclusion was that the increased binding energy of the  $[Rn]5f^{12}6d^1 7s^2$  configuration over the  $[Rn]5f^{13}7s^2$  configuration for mendelevium was not enough to compensate for the energy needed to promote one 5f electron to 6d, as is true also for the very late actinides: thus einsteinium, fermium, mendelevium, and nobelium were expected to be divalent metals.<sup>[12]</sup> The increasing predominance of the divalent state well before the actinide series concludes is attributed to the relativistic stabilization of the 5f electrons, which increases with increasing atomic number.<sup>[14]</sup> Thermochromatographic studies with trace quantities of mendelevium by Zvara and Hübener from 1976 to 1982 confirmed this prediction.<sup>[11]</sup> In 1990, Haire and Gibson estimated mendelevium metal to have an enthalpy of sublimation between 134 and 142  $\text{kJ}\cdot\text{mol}^{-1}$ .<sup>[11]</sup> Divalent mendelevium metal should have a metallic radius of around  $(194 \pm 10)$  pm.<sup>[11]</sup> Like the other divalent late actinides (except the once again trivalent lawrencium), metallic mendelevium should assume a face-centered cubic crystal structure.<sup>[1]</sup> Mendelevium's melting point has been estimated at 827 °C, the same value as that predicted for the neighboring element nobelium.<sup>[15]</sup> Its density is predicted to be around  $10.3 \pm 0.7 \text{ g}\cdot\text{cm}^{-3}$ .<sup>[1]</sup>

## Chemical

The chemistry of mendelevium is mostly known only in solution, in which it can take on the +3 or +2 oxidation states. The +1 state has also been reported, but has not yet been confirmed.<sup>[16]</sup>

Before mendelevium's discovery, Seaborg and Katz predicted that it should be predominantly trivalent in aqueous solution and hence should behave similarly to other tripositive lanthanides and actinides. After the synthesis of mendelevium in 1955, these predictions were confirmed, first in the observation at its discovery that it eluted just after fermium in the trivalent actinide elution sequence from a cation-exchange column of resin, and later the 1967 observation that mendelevium could form insoluble hydroxides and fluorides that coprecipitated with trivalent lanthanide

### Miscellanea

**Crystal structure** face-centered cubic (fcc)



(predicted)<sup>[1]</sup>

**CAS Number** 7440-11-1

### History

**Naming** after Dmitri Mendeleev

**Discovery** Lawrence Berkeley National Laboratory (1955)

### Most stable isotopes of mendelevium

iso	NA	half-life	DM	DE (MeV)	DP
<b>257Md</b>	syn	5.52 h	ε	0.406	<sup>257</sup> Fm
			α	7.558	<sup>253</sup> Es
			SF	–	–
<b>258Md</b>	syn	51.5 d	ε	1.230	<sup>258</sup> Fm
<b>260Md</b>	syn	31.8 d	SF	–	–
			α	7.000	<sup>256</sup> Es
			ε	–	<sup>260</sup> Fm
			β <sup>−</sup>	1.000	<sup>260</sup> No

salts.<sup>[16]</sup> Cation-exchange and solvent extraction studies led to the conclusion that mendelevium was a trivalent actinide with an ionic radius somewhat smaller than that of the previous actinide, fermium.<sup>[16]</sup> Mendelevium can form coordination complexes with 1,2-cyclohexanedinitrilotetraacetic acid (DCTA).<sup>[16]</sup>

In reducing conditions, mendelevium(III) can be easily reduced to mendelevium(II), which is stable in aqueous solution.<sup>[16]</sup> The standard reduction potential of the  $E^\circ(\text{Md}^{3+} \rightarrow \text{Md}^{2+})$  couple has been variously estimated as  $-0.10 \text{ V}$  or  $-0.20 \text{ V}$ .<sup>[16]</sup> In comparison,  $E^\circ(\text{Md}^{3+} \rightarrow \text{Md}^0)$  should be around  $-1.74 \text{ V}$ , and  $E^\circ(\text{Md}^{2+} \rightarrow \text{Md}^0)$  should be around  $-2.5 \text{ V}$ .<sup>[16]</sup> Mendelevium(II)'s elution behavior has been compared with that of strontium(II) and europium(II).<sup>[16]</sup>

In 1973, mendelevium(I) was reported to have been produced by Russian scientists, who obtained it by reducing higher oxidation states of mendelevium with samarium(II). It was found to be stable in neutral water-ethanol solution and be homologous to caesium(I). However, later experiments found no evidence for mendelevium(I) and found that mendelevium behaved like divalent elements when reduced, not like the monovalent alkali metals.<sup>[16]</sup> Nevertheless, the Russian team conducted further studies on the thermodynamics of cocrystallizing mendelevium with alkali metal chlorides, and concluded that mendelevium(I) had formed and could form mixed crystals with divalent elements, thus cocrystallizing with them. The status of the +1 oxidation state is still tentative.<sup>[16]</sup>

Although  $E^\circ(\text{Md}^{4+} \rightarrow \text{Md}^{3+})$  was predicted in 1975 to be  $+5.4 \text{ V}$ , suggesting that mendelevium(III) could be easily oxidized to mendelevium(IV), 1967 experiments with the strong oxidizing agent sodium bismuthate were unable to oxidize mendelevium(III) to mendelevium(IV).<sup>[16]</sup>

## Atomic

A mendelevium atom has 101 electrons, of which at least three (and perhaps four) can act as valence electrons. They are expected to be arranged in the configuration  $[\text{Rn}]5f^{13}7s^2$  (ground state term symbol  $^2F_{7/2}$ ), although experimental verification of this electron configuration had not yet been made as of 2006.<sup>[17]</sup> In forming compounds, three valence electrons may be lost, leaving behind a  $[\text{Rn}]5f^{12}$  core: this conforms to the trend set by the other actinides with their  $[\text{Rn}] 5f^n$  electron configurations in the tripositive state. The first ionization potential of mendelevium was measured to be at most  $(6.58 \pm 0.07) \text{ eV}$  in 1974, based on the assumption that the 7s electrons would ionize before the 5f ones;<sup>[18]</sup> this value has since not yet been refined further due to mendelevium's scarcity and high radioactivity.<sup>[19]</sup> The ionic radius of hexacoordinate  $\text{Md}^{3+}$  had been preliminarily estimated in

1978 to be around 91.2 pm;<sup>[16]</sup> 1988 calculations based on the logarithmic trend between distribution coefficients and ionic radius produced a value of 89.6 pm, as well as an enthalpy of hydration of  $-(3654 \pm 12) \text{ kJ}\cdot\text{mol}^{-1}$ .<sup>[16]</sup>  $\text{Md}^{2+}$  should have an ionic radius of 115 pm and hydration enthalpy  $-1413 \text{ kJ}\cdot\text{mol}^{-1}$ ;  $\text{Md}^+$  should have ionic radius 117 pm.<sup>[16]</sup>

## Isotopes

Sixteen isotopes of mendelevium are known, with mass numbers from 245 to 260; all are radioactive.<sup>[20]</sup> Additionally, five nuclear isomers are known:  $^{245\text{m}}\text{Md}$ ,  $^{247\text{m}}\text{Md}$ ,  $^{249\text{m}}\text{Md}$ ,  $^{254\text{m}}\text{Md}$ , and  $^{258\text{m}}\text{Md}$ .<sup>[2][21]</sup> Of these, the longest-lived isotope is  $^{258}\text{Md}$  with a half-life of 51.5 days, and the longest-lived isomer is  $^{258\text{m}}\text{Md}$  with a half-life of 58.0 minutes.<sup>[2][21]</sup> Nevertheless, the slightly shorter-lived  $^{256}\text{Md}$  (half-life 1.17 hours) is more often used in chemical experimentation because it can be produced in larger quantities from alpha particle irradiation of einsteinium.<sup>[20]</sup> After  $^{258}\text{Md}$ , the next most stable mendelevium isotopes are  $^{260}\text{Md}$  with a half-life of 31.8 days,  $^{257}\text{Md}$  with a half-life of 5.52 hours,  $^{259}\text{Md}$  with a half-life of 1.60 hours, and  $^{256}\text{Md}$  with a half-life of 1.17 hours. All of the remaining mendelevium isotopes have half-lives that are less than an hour, and the majority of these have half-lives that are less than 5 minutes.<sup>[2][20][21]</sup>

The half-lives of mendelevium isotopes mostly increase smoothly from  $^{245}\text{Md}$  onwards, reaching a maximum at  $^{258}\text{Md}$ .<sup>[2][20][21]</sup> Experiments and predictions suggest that the half-lives will then decrease, apart from  $^{260}\text{Md}$  with a half-life of 31.8 days,<sup>[2][20][21]</sup> as spontaneous fission becomes the dominant decay mode<sup>[2]</sup> due to the mutual repulsion of the protons posing a limit to the island of relative stability of long-lived nuclei in the actinide series.<sup>[22]</sup>

Mendelevium-256, the chemically most important isotope of mendelevium, decays through electron capture 90.7% of the time and alpha decay 9.9% of the time.<sup>[20]</sup> It is most easily detected through the spontaneous fission of its electron-capture daughter fermium-256, but in the presence of other nuclides that undergo spontaneous fission, alpha decays at the characteristic energies for mendelevium-256 (7.205 and 7.139 MeV) can provide more useful identification.<sup>[23]</sup>

## Source

- Wikipedia: Mendelevium (<https://en.wikipedia.org/wiki/Mendelevium>)