{{NoteTA

|T=zh-cn:砹; zh-hk:砈; zh-tw:砈;

|G1=化學

}}

{{Elementbox

|name=砹

|enname=Astatine

|number=85

|symbol=At

|pronounce={{IPAc-en|ˈ|æ|s|t|ə|t|iː|n}} {{Respell|AS|tə-teen}} <br /> or {{IPAc-en|ˈ|æ|s|t|ə|t|ɪ|n}} {{Respell|AS|tə-tin}}

|left=[[釙]]

|right=[[氡]]

|above=[[碘]]

|below=[[Uus]]

|series=類金屬

|series comment=（未定，有時歸為[[鹵素]]，可能為[[金屬]]）<ref>{{cite journal|doi=10.1103/PhysRevLett.111.116404|title=Condensed Astatine: Monatomic and Metallic|year=2013|last1=Hermann|first1=Andreas|last2=Hoffmann|first2=Roald|last3=Ashcroft|first3=N. W.|journal=Physical Review Letters|volume=111|issue=11}}</ref>

|group=17

|period=6

|block=p

|series color=

|phase color=

|appearance=未知，可能是金屬質

<includeonly>|image name=</includeonly>

|image name comment=

|image name 2=

|image name 2 comment=

|image size = 150

|atomic mass=(210)

|atomic mass 2=

|atomic mass comment=

|electron configuration=&#91;[[氙]]&#93; 4f<sup>14</sup> 5d<sup>10</sup> 6s<sup>2</sup> 6p<sup>5</sup>

|electrons per shell=2, 8, 18, 32, 18, 7

|electron shell image=Electron shell 085 Astatine (metalloid) - no label.svg

|color=

|phase=固體

|phase comment=

|density gplstp=

|density gpcm3nrt=（At<sub>2</sub>）6.2﹣6.5（預測）<ref name=Bonchev>{{cite journal |last1=Bonchev |first1=Danail |last2=Kamenska |first2=Verginia |year=1981 |title=Predicting the properties of the 113–120 transactinide elements |journal=The Journal of Physical Chemistry |volume=85 |issue=9 |pages=1177–86 |publisher=ACS Publications |doi=10.1021/j150609a021 |url=http://www.researchgate.net/publication/239657207\_Predicting\_the\_properties\_of\_the\_113\_to\_120\_transactinide\_elements}}</ref>

|density gpcm3mp=

|melting point K=575

|melting point C=302

|melting point F=576

|boiling point K=610

|boiling point C=337

|boiling point F=639

|triple point K=

|triple point kPa=

|critical point K=

|critical point MPa=

|heat fusion=

|heat vaporization=（At<sub>2</sub>）54.39

|heat capacity=

|vapor pressure 1=361

|vapor pressure 10=392

|vapor pressure 100=429

|vapor pressure 1 k=475

|vapor pressure 10 k=531

|vapor pressure 100 k=607

|vapor pressure comment=

|crystal structure=

|oxidation states='''−1''', '''+1''', +3, +5, +7

|oxidation states comment=

|electronegativity=2.2

|number of ionization energies=1

|1st ionization energy=899.003<ref>{{cite journal |last1=Rothe |first1=S. |last2=Andreyev |first2=A. N. |last3=Antalic |first3=S. |last4=Borschevsky |first4=A. |last5=Capponi |first5=L. |last6=Cocolios |first6=T. E. |last7=De Witte |first7=H. |last8=Eliav |first8=E. |last9=Fedorov |first9=D. V. | displayauthors = 8

|year=2013 |title=Measurement of the first ionization potential of astatine by laser ionization spectroscopy |journal=Nature Communications |volume=4 |publisher= |doi=10.1038/ncomms2819 |url=http://www.researchgate.net/publication/236836716\_Measurement\_of\_the\_first\_ionization\_potential\_of\_astatine\_by\_laser\_ionization\_spectroscopy |last10=Fedosseev |first10=V. N. |last11=Fink |first11=D. A. |last12=Fritzsche |first12=S. |last13=Ghys |first13=L. |last14=Huyse |first14=M. |last15=Imai |first15=N. |last16=Kaldor |first16=U. |last17=Kudryavtsev |first17=Yuri |last18=Köster |first18=U. |last19=Lane |first19=J. F. W. |last20=Lassen |first20=J. |last21=Liberati |first21=V. |last22=Lynch |first22=K. M. |last23=Marsh |first23=B. A. |last24=Nishio |first24=K. |last25=Pauwels |first25=D. |last26=Pershina |first26=V. |last27=Popescu |first27=L. |last28=Procter |first28=T. J. |last29=Radulov |first29=D. |last30=Raeder |first30=S. |pages=1835– |pmid=23673620 |pmc=3674244}}</ref>

|atomic radius=

|covalent radius=150

|Van der Waals radius=202

|magnetic ordering=

|electrical resistivity=

|electrical resistivity at 0=

|electrical resistivity at 20=

|thermal conductivity=1.7

|thermal conductivity 2=

|thermal diffusivity=

|thermal expansion=

|thermal expansion at 25=

|speed of sound=

|speed of sound rod at 20=

|speed of sound rod at r.t.=

|Young's modulus=

|Shear modulus=

|Bulk modulus=

|Poisson ratio=

|Mohs hardness=

|Vickers hardness=

|Brinell hardness=

|CAS number=7440-68-8

|isotopes=

{{Elementbox\_isotopes\_decay2 | mn=209 | sym=At

| na=[[人造放射性同位素|人造]] | hl=5.41小時

| dm1=[[β衰變|β<sup>+</sup>]] | de1=3.486 | pn1=209 | ps1=[[釙|Po]]

| dm2=[[α衰變|α]] | de2=5.758 | pn2=205 | ps2=[[鉍|Bi]]}}

{{Elementbox\_isotopes\_decay2 | mn=210 | sym=At

| na=syn | hl=8.1小時

| dm1=β<sup>+</sup> | de1=3.981 | pn1=210 | ps1=Po

| dm2=α | de2=5.632 | pn2=206 | ps2=Bi}}

{{Elementbox\_isotopes\_decay2 | mn=211 | sym=At

| na=syn | hl=7.21小時

| dm1=[[電子捕獲|ε]] | de1=0.786 | pn1=211 | ps1=Po

| dm2=α | de2=5.983 | pn2=207 | ps2=Bi}}

|isotopes comment=

|discovered by=戴爾·科爾森、肯尼斯·羅斯·麥肯西和[[埃米利奧·塞格雷]]

|discovery date=1940

}}

'''砹'''（'''Astatine'''，-{zh-cn:台湾、港澳译作'''砈'''; zh-tw:中國大陸譯作'''砹''';}-，舊訛作「'''鈪'''」、「'''銰'''」）是一種[[放射性]][[化學元素]]，符號為'''At'''，原子序為85。地球上所有的砹都是更重的元素衰變過程中產生的。其[[同位素]]壽命都很短，其中最穩定的是砹-210，[[半衰期]]為8.5小時。<ref>Price, Andy (2004-12-20). "Francium". Retrieved 2012-02-19.

</ref>科學家對砹所知甚少。砹在元素週期表中位於[[碘]]之下，而砹的已知特性符合從碘推算出的特性。其他有關砹的信息都是通過這種關係估算得出的。

人們尚未觀測過砹元素的單質，因為所有肉眼能觀察到的砹元素量都會產生大量的放射性熱量，使它瞬間氣化。砹的熔點很可能比碘高很多，與[[鉍]]和釙相近。砹的化學屬性與其他[[鹵素]]相似：砹會與包括其他鹵素在內的非金屬形成共價化合物，且估計能夠與[[鹼金屬]]和[[鹼土金屬]]形成砹化物。不過，砹正離子的化學屬性則有別於較輕的鹵素。壽命第二長的砹-211同位素是唯一一種具有商業應用的砹同位素，目前在醫學中用作[[α粒子]]射源，以診斷及治療某些疾病。由於放射性極強，砹的使用量非常低。

[[伯克利加州大學]]的戴爾·科爾森（Dale R. Corson）、肯尼斯·羅斯·麥肯西（Kenneth Ross MacKenzie）和[[埃米利奧·塞格雷]]在1940年發現了砹元素。由於產物極不穩定，所以他們根據[[希臘文]]「αστατος」（astatos，意為「不穩定」）將其命名為「astatine」。三年後，該元素被發現存在於大自然中，是在[[地殼]]中豐度最低的非[[超鈾元素]]，任一時刻的總量不到1克。<ref name="Hollerman 2001 423">{{cite book|last=Hollerman|first=Arnold|title=Inorganic Chemistry|year=2001|publisher=Academic Press|location=Berlin|isbn=0123526515|page=423|url=http://books.google.com/books/about/Inorganic\_Chemistry.html?id=Mtth5g59dEIC}}</ref>自然界中的重元素經各種衰變途徑一共產生6種[[砹的同位素]]，[[原子量]]介乎214和219，但最穩定的兩種同位素砹-210和砹-211都不存在於自然中。

==性質==

砹具有極高的放射性。所有砹同位素的[[半衰期]]都在12小時以下，並會衰變成[[鉍]]、[[釙]]、[[氡]]以及其他砹同位素。在首101種化學元素中，只有[[鍅]]的穩定性比砹低。<ref name="ffff">{{cite journal |first1=G.|last1=Audi|first2=A. H.|last2=Wapstra|first3=C. |last3=Thibault |first4=J.|last4=Blachot|first5=O.|last5=Bersillon |year=2003 |title=The NUBASE evaluation of nuclear and decay properties |url=http://www.nndc.bnl.gov/amdc/nubase/Nubase2003.pdf |journal=[[Nuclear Physics A]] |volume=729 |pages=3–128 |doi=10.1016/j.nuclphysa.2003.11.001 |bibcode=2003NuPhA.729....3A}}</ref>

人們對砹的宏觀特性所知甚少。<ref>{{cite book | title = Chemistry of the elements|edition=2nd| year = 2002 | page = 855 | publisher = Butterworth-Heinemann | isbn = 0-7506-3365-4 | last1 = Greenwood | first1 = Norman Neill | last2 = Earnshaw | first2 = Alan }}</ref>砹的壽命太短，因此可用於研究的量極為有限。<ref name="MoreAt">{{cite book|title=Inorganic Chemistry|publisher=John Wiley and Sons|page=423|first1=Egon|last1=Wiberg|first2=Nils|last2=Wiberg |first3=Arnold Frederick|last3=Holleman|year=2001 | isbn = 978-0-12-352651-9 |url = http://books.google.com/books?id=Mtth5g59dEIC&dq=978-0-12-352651-9&q=astatine#v=snippet&q=astatine&f=false}}</ref>可觀量的砹元素會釋放大量輻射，將自身加熱，迅速氣化。<ref name="Emsley"/> 砹一般歸為非金屬或[[類金屬]]。<ref>{{cite book | title = Chemistry & Chemical Reactivity | year = 2011 | edition = 8 | page = 65 | publisher = Cengage Learning | isbn = 978-0-8400-4828-8 | last1 = Kotz | first1 = John C. | last2 = Treichel | first2 = Paul M. | last3 = Townsend | first3 = John}}</ref><ref name="Jahn2010">{{cite book | title = MIPS and their role in the exchange of metalloids | series = Advances in Experimental Biology and Medicine | year = 2010 | last = Jahn | first = Thomas P. | page = 41 | volume = 679 | publisher = Springer | isbn = 978-1-4419-6314-7 | url = http://books.google.com/books?id=ayGhnf3A-L0C&dq=MIPS+and+their+role+in+the+exchange+of+metalloids&q=astatine#v=snippet&q=astatine&f=false}}</ref>有科學家認為，砹能夠形成[[凝聚態物理學|凝聚態]]金屬物質。<ref>{{cite book | title = Concise chemistry of the elements | year = 2002 | pages = 65, 122 | publisher = Horwood | isbn = 978-1-898563-71-6 | last1 = Siekierski | first1 = Slawomir | last2 = Burgess | first2 = John | url = http://books.google.com/books?id=1I8sByjBONoC&lpg=PA3&vq=astatine&pg=PA3#v=snippet&q=astatine&f=false}}</ref>

===物理===

砹的大部份物理特性都是根據理論或實驗證據推算而得的。<ref>{{cite book|title=Supplement to Mellor's comprehensive treatise on inorganic and theoretical chemistry, Supplement II, Part 1, (F, Cl, Br, I, At)| pages=1064‒1079|chapter=Astatine|year=1956|first=A. G.|last=Maddock }}</ref>例如，鹵素的原子量越高，色澤就越深（[[氟]]幾乎無色，[[氯]]呈亮綠色，[[溴]]呈棕色，而碘呈深灰或紫色）。如果該趨勢持續，那麼砹將會具有黑色金屬質地。<ref>{{cite book | url = http://books.google.com/?id=NKUNAQAAIAAJ | title = Chemistry: A first course in modern chemistry | year = 1961 | page = 313 | publisher = Ginn | last1 = Garrett | first1 = Alfred Benjamin | last2 = Richardson | first2 = John B. | last3 = Kiefer | first3 = A. S.}}</ref><ref>{{cite book | url = http://www.britannica.com/nobelprize/print?articleId=110617&fullArticle=true&tocId=81198 |chapter = Transuranium element | authorlink=Glenn T. Seaborg | last= Seaborg | first = Glenn T. | title = Encyclopædia Britannica's guide to the Nobel prizes | year = 2012}}</ref><ref>{{cite book|title=Chemistry Expression: An Inquiry Approach. 'O' Level Special/Express [Textbook]|publisher=John Wiley and Sons|page=300|first=Hock Leong|last=Oon|year=2007 | isbn = 978-981-271-162-5 |url = http://books.google.com/?id=jd-BR-nfzIoC&dq=Chemistry+Expression%3A+An+Inquiry+Approach&q=astatine#v=snippet&q=astatine&f=false}}</ref>根據類似的趨勢，可推斷砹的[[熔點]]和[[沸點]]比輕鹵素都要高，估值分別為575 [[開爾文|K]]和610 K。<ref name="Hansen2009">{{cite book | title = The Science of Construction Materials | year = 2009 | last = Hansen | first = Per Freiesleben | editor-first = Ole Mejlhede | editor-last = Jensen | page = B.2 | publisher = Springer | isbn = 978-3-540-70897-1 | url = http://books.google.com/books?id=3HIbXNnGkbwC&lpg=SL2-PA2&vq=astatine&dq=The%20Science%20of%20Construction%20Materials&pg=SL2-PA2#v=snippet&q=astatine&f=false }}</ref>然而一些實驗證據顯示，砹的熔點和沸點有可能比理論預測的低。<ref name="boiling\_point\_chromatography" />砹的[[昇華]]作用比碘緩慢，其[[蒸氣壓]]也較低。<ref name="MoreAt" />在[[室溫]]下把砹置於玻璃表面，1小時之後一半的砹會氣化。{{efn|但是，如果砹置於[[金]]或[[鉑]]表面上，則這一「半昇華期」可以長達16小時。這可能是砹與[[貴金屬]]間某種未知的交互作用所導致的。{{sfn|Lavrukhina|Pozdnyakov|1966|p=253}}}}

固體砹的晶體結構是未知的。<ref>{{cite book | title = The structures of the elements | year = 1982 | page = 400 | publisher = Robert E. Krieger | isbn = 978-0-89874-230-5 | last = Donohue | first = Jerry | url=http://books.google.com/?id=MshQAAAAYAAJ&dq=The+structures+of+the+elements&q=astatine#search\_anchor}}</ref>尚未有證據確切證實或否定砹的雙原子分子（At<sub>2</sub>）的存在。<ref>{{cite journal | language = French| title = Etude de la formation en phase gazeuse de composés interhalogénés d'astate par thermochromatographie | trans\_title = Study of the gas-phase formation of interhalogen compounds of astatine by [[wikt:thermochromatography|thermochromatography]] | last1= Merinis | first1 = J. | last2= Legoux | first2 = G. | last3 = Bouissières | first3 = G. | journal = Radiochemical and Radioanalytical Letters | volume = 11 | pages = 59–64 | year = 1972 | issue = 1 }}</ref><ref>{{cite journal | title = The mechanism of the reaction of elementary astatine with organic solvents | last1= Takahashi | first1 = N. | last2= Otozai | first2 = K. | journal = Journal of Radioanalytical and Nuclear Chemistry | volume = 103 | pages = 1‒9 | year = 1986 | doi =10.1007/BF02165358 }}</ref><ref>{{cite conference | title = Chemical behavior of astatine molecules | last1= Takahashi | first1 = N. | last2= Yano | first2 = D. | last3= Baba | first3 = H. | booktitle = Proceedings of the international conference on evolution in beam applications, Takasaki, Japan, November 5‒8, 1991 | pages = 536‒539| year = 1992 }}</ref>{{sfn|Zuckerman|Hagen|1989|pp=21–22 (21)}}{{sfn|Kugler|Keller|1985|pp=110, 116, 210–211, 224}}某些文獻主張At<sub>2</sub>並不存在，並指出它從未被觀測到；<ref name=Meyers2002>{{Cite encyclopedia | encyclopedia = Encyclopedia of physical science and technology | edition=3rd| title = Halogen chemistry| year = 2001 | last = Meyers | first = Robert Allen | pages = 197–222 (202) | isbn = 978-0-12-227410-7 | publisher = Academic Press}}</ref><ref>{{cite encyclopedia | last1= Keller | first1 = Cornelius| last2= Wolf | first2 = Walter | last3 = Shani | first3 = Jashovam| encyclopedia = Ullmann's Encyclopedia of Industrial Chemistry | volume = 31 | pages = 89–117 (96) | year = 2011 | doi =10.1002/14356007.o22\_o15 | title = Ullmann's Encyclopedia of Industrial Chemistry | isbn = 3-527-30673-0 | chapter= Radionuclides, 2. Radioactive Elements and Artificial Radionuclides}}</ref>另一些文獻則表示或暗示它是存在的。<ref name="boiling\_point\_chromatography">{{cite journal | title = Estimation chemical form boiling point elementary astatine by radio gas chromatography | last1= Otozai | first = K. | last2= Takahashi | first2 = N. | journal = Radiochimica Acta | volume = 31 | pages = 201‒203 | year = 1982 |url = http://www.mendeley.com/research/estimation-chemical-form-boiling-point-elementary-astatine-radio-gas-chromatography/ | issue = 3‒4}}</ref><ref>{{cite book | title = Chemistry | edition=8th | year = 2008 | page = 56 | publisher = Cengage Learning | isbn = 0-547-12532-1 | last1 = Zumdahl | first1 = Stephen S. | last2 = Zumdahl | first2 = Susan A | url = http://books.google.com/?id=LLWkH82PNbYC&lpg=PA56&vq=astatine&dq=0547125321&pg=PA57#v=snippet&q=astatine&f=false}}</ref><ref name=Housecroft>{{cite book | title = Inorganic chemistry | edition=3rd| year = 2008 | page = 533 | publisher = Pearson Education | isbn = 978-0-13-175553-6 | last1 = Housecroft | first1 = Catherine E. | last2 = Sharpe | first2 = Alan G.}}</ref>儘管爭議持續，但是砹雙原子分子的許多屬性都有理論的預測值，{{sfn|Kugler|Keller|1985|p=116}}如密度為6.2至6.5 g/cm<sup>3</sup>。<ref name=Bonchev>{{cite journal |last1=Bonchev |first1=Danail |last2=Kamenska |first2=Verginia |year=1981 |title=Predicting the properties of the 113–120 transactinide elements |journal=The Journal of Physical Chemistry |volume=85 |issue=9 |pages=1177–86 |publisher=ACS Publications |doi=10.1021/j150609a021 |url=http://pubs.acs.org/doi/abs/10.1021/j150609a021 |accessdate=May 6, 2013}}</ref>

===化學===

砹的許多化學屬性都是通過在極稀釋的砹溶液中用[[放射性示蹤劑]]進行研究得出的。<ref name=Housecroft/><ref>{{cite book | title = College chemistry | year = 1960 | page = 457 | publisher = Appleton-Century-Crofts | last1 = Smith | first1 = A. | last2 = Ehret | first2 = W. F.}}</ref>大部份屬性，例如負離子的形成等，都與其他鹵素相符。<ref name="MoreAt" />砹也同時擁有一些金屬的特性，比如會[[電鍍]]到[[陰極]]上，{{efn|這也有可能只是吸附作用。<ref>{{cite journal|doi=10.1007/BF02037143|journal=Journal of Radioanalytical and Nuclear Chemistry|volume=83|pages=291–299|title=Chemical properties of positive singly charged astatine ion in aqueous solution|year=1984|first1=M.|last1=Milanov|first2=V.|last2=Doberenz|first3=V. A.|last3=Khalkin|first4=A.|last4=Marinov|issue=2}}</ref>}}在[[氫氯酸]]中與金屬的硫化物[[共沉澱]]，{{sfn|Lavrukhina|Pozdnyakov|1966|p=235}}以及會在強酸中形成正離子。{{sfn|Lavrukhina|Pozdnyakov|1966|p=235}}

砹在[[鮑林標度]]上的[[電負性]]為2.2，比碘的2.66低，與氫相同。但是[[砹化氫]]（HAt）的負電荷預計靠向氫原子，<ref>{{cite journal|last1=Dolg|first1=M.|last2=Kuchle|first2=W.|last3=Stoll|first3=H.|last4=Preuss|first4=H.|last5=Schwerdtfeger|first5=P.|title=''Ab Initio'' pseudopotentials for Hg to Rn: II. Molecular calculations on the hydrides of Hg to At and the fluorides of Rn|journal=Molecular Physics|volume=74|issue=6|pages=1265–1285 (1265, 1270, 1282)|year=1991|doi=10.1080/00268979100102951|bibcode = 1991MolPh..74.1265D }}</ref><ref>{{cite journal|last1=Saue|first1=T.|last2=Faegir|first2=K.|last3=Gropen|first3=O.|title=Relativistic effects on the bonding of heavy and superheavy hydrogen halides|journal=Chemical Physics Letters|volume=263|pages=360–366 (361–362)|year=1996|doi=10.1016/S0009-2614(96)01250-X|issue=3–4|bibcode = 1996CPL...263..360S }}</ref><ref name="H-">{{cite book|title=Relativistic Methods for Chemists|first=Maria|last=Barysz|page=79|publisher=Springer|year=2010 | isbn = 978-1-4020-9974-8 | url=http://books.google.com/books?id=QbDEC3oL7uAC&lpg=PA79&vq=astatine&dq=Astatine&pg=PA79#v=snippet&q=astatine&f=false}}</ref><ref>{{cite journal|last=Thayer|first=John S.|title=Relativistic effects and the chemistry of the heaviest main-group elements|journal=Journal pf Chemical Education|volume=82|issue=11|pages=1721–1727 (1725)|year=2005|doi=10.1021/ed082p1721|bibcode = 2005JChEd..82.1721T }}</ref>且砹在[[阿萊﹣羅周標度]]（Allred-Rochow scale）上的電負性為1.9，比氫的2.2低，所以「氫化砹」可能是更準確的名稱。<ref>{{cite web | last = Winter | first = Mark J. | title = Electronegativity (Allred-Rochow): periodicity | work = WebElements | url = http://www.webelements.com/periodicity/electroneg\_allred\_rochow/ | accessdate =8 April 2012}}</ref>{{efn|根據阿萊﹣羅周標度所用的算法，氫的電負性其實會與[[氧]]的3.5相近，這並不合理。因此，氫的電負性需指定為2.2。<ref>{{cite book | title = Inorganic Substances: A Prelude to the Study of Descriptive Inorganic Chemistry | year = 1990 | page = 135 | publisher = Cambridge University Press | last = Smith | first = Derek William| isbn = 0-521-33738-0 | url = http://books.google.com/books?id=Wipsx\_M5HjMC&lpg=PA135&vq=Allred-Rochow&pg=PA135#v=snippet&q=Allred-Rochow&f=false | series = Cambridge Texts in Chemistry and Biochemistry}}</ref>}}

==化合物==

砹的化學活性比碘低，因此是鹵素中活性最低的元素。<ref name="Anders">{{cite journal | journal = Annual Review of Nuclear Science | volume = 9 | pages = 203–220 | year = 1959 | doi = 10.1146/annurev.ns.09.120159.001223 | title = Technetium and astatine chemistry | first = E. | last = Anders|bibcode = 1959ARNPS...9..203A }} {{subscription required}}</ref>科學家成功合成了多種砹[[化合物]]，量極少。這些化合物會因砹的放射性而迅速瓦解，因此研究機會非常寶貴。實驗一般把稀釋砹溶液混合在大量的碘溶液中。碘作為載體，可保證有足夠的量進行化學分析，如過濾和沉澱等。<ref name="Ru1968" /><ref>{{cite journal | journal =Analyst| year = 1952| volume = 77 | pages = 774–777| doi = 10.1039/AN9527700774 | title = Section 5: radiochemical methods. Analytical chemistry of astatine | first1 = A. H. W. | last1 = Aten, Jun. | last2 =Doorgeest | first2 =T. | last3 =Hollstein | first3 =U.| last4 =Moeken | first4 =H. P. | issue =920|bibcode = 1952Ana....77..774A }} {{subscription required}}</ref>{{efn|碘會在水中與砹反應，但仍可以作為載體，因為這些反應所需的不但有I<sup>2</sub>，還有碘離子I<sup>-</sup>。{{sfn|Zuckerman|Hagen|1989|p=31}}{{sfn|Zuckerman|Hagen|1989|p=38}}}}

[[File:Hydrogen-astatide-calculated-3D-sf.png|thumb|left|135px|[[砹化氫]]的[[空間填充模型]]]]

早期研究砹化學的科學家已發現，砹可以和氫形成[[砹化氫]]。{{sfn|Kugler|Keller|1985|p=211}}砹在（稀釋）[[硝酸]]中會輕易氧化、酸化，形成At<sup>0</sup>或At<sup>+</sup>。加入[[銀]](I)會使小部份砹沉澱出來，形成砹化銀(I)（AgAt）。相比之下，碘則不會被氧化，且會沉澱為[[碘化銀|碘化銀(I)]]。<ref name="MoreAt" />{{sfn|Kugler|Keller|1985|pp=109–110, 129, 213}}

已知的金屬砹化物很少，<ref name="Emsley"/>其中包括[[鈀]]、銀和[[鉛]]的砹化物。利用推算的方法可以得出砹化銀以及各種鹼金屬和鹼土金屬的砹化物的屬性。{{sfn|Kugler|Keller|1985|pp=214–218}}

[[File:Astatine-iodide-3D-vdW.png|thumb|right|200px|一碘化砹是已知最重的[[互鹵化物]]。]]

在氣體狀態下，砹會與其他鹵素碘、[[溴]]和[[氯]]反應，形成雙原子[[互鹵化物]]，如AtI、AtBr和AtCl。{{sfn|Zuckerman|Hagen|1989|p=31}}Atl和AtBr可在水中產生：砹與碘/碘離子溶液反應形成AtI，砹與碘/[[一溴化碘]]/溴離子溶液反應形成AtBr。過量碘離子或溴離子會導致產生{{chem|AtBr|2|-}}和{{chem|AtI|2|-}}離子；{{sfn|Zuckerman|Hagen|1989|p=31}}在氯離子溶液中，反應會與氯離子達致平衡，產生{{chem|AtCl|2|-}}或{{chem|AtBrCl|-}}。{{sfn|Zuckerman|Hagen|1989|p=38}}在硝酸溶液中用[[重鉻酸]]氧化砹元素，加入氯離子會產生一種分子，可能是AtCl或AtOCl。用類似的方法可以產生{{chem|AtOCl|2|-}}或{{chem|AtCl|2|-}}。{{sfn|Zuckerman|Hagen|1989|p=31}}在利用電漿離子源的[[質譜儀]]中，將其他鹵素的氣體加入到含有砹且充滿[[氦]]氣的空間中，會分別產生[AtI]<sup>+</sup>、[AtBr]<sup>+</sup>和[AtCl]<sup>+</sup>。這有助證明砹在電漿離子態下可以形成穩定的中性分子。{{sfn|Zuckerman|Hagen|1989|p=31}}人們尚未發現砹的任何氟化物。科學家猜測，這是因為這種化合物反應性極強，可能在形成後瞬間與容器玻璃壁反應產生不揮發的物質。{{efn|使用[[三氟化氯]]對砹進行氟化所產生的物質粘附在玻璃的表面。然而反應卻形成了[[一氟化氯]]、氯氣和[[四氟化硅]]。<ref>{{cite journal |first1=E. H.|last1=Appelman|first2=E. N.|last2=Sloth|first3=M. H. |last3=Studier |year=1966 |title=Observation of astatine compounds by time-of-flight mass spectrometry |journal=Inorganic chemistry |volume=5 |issue = 5|pages=766–769 |doi=10.1021/ic50039a016}}</ref>該實驗進行後十年，理論預測該化合物確實不具揮發性。這與其他鹵素的對應化合物屬性相駁，但與氟化氡相似。<ref>{{cite journal |first1=K. S.|last1=Pitzer|year=1975 |title=Fluorides of radon and element 118 |journal=Journal of the Chemical Society, Chemical Communications |volume=5 |issue = 5|pages=760b–761 |doi=10.1039/C3975000760B}}</ref>}}雖然氟化砹有可能能夠形成，但實驗需要用到液態鹵素氟化物。{{sfn|Kugler|Keller|1985|pp=112, 192–193}}{{sfn|Zuckerman|Hagen|1989|p=31}}

砹在[[高氯酸]]溶液中與某些氧化劑（例如溴和[[過硫酸鈉]]）反應，會產生AtO<sup>–</sup>、{{chem|AtO|2|-}}和AtO<sup>+</sup>。{{sfn|Kugler|Keller|1985|p=111}}<ref name="MoreAt" />在[[氫氧化鉀]]溶液中，[[次氯酸鉀]]能把砹氧化，形成{{chem|AtO|3|-}}。{{sfn|Kugler|Keller|1985|p=222}}{{sfn|Zuckerman|Hagen|1989|pp=190–191}}用[[二氟化氙]]（在熱鹼性溶液中）或[[高碘酸]]（在中性或鹼性溶液中）再次進行氧化，可產生高砹酸離子{{chem|AtO|4|-}}。不過，這種離子只有在中性或鹼性溶液中才會穩定。{{sfn|Kugler|Keller|1985|pp=112, 192–193}}在酸性溶液中，一價砹會和[[碘酸銀|碘酸銀(I)]]和[[重鉻酸鉈|重鉻酸鉈(I)]]等不可溶金屬鹽[[共沉澱]]。有科學家因此認為，砹能夠以正離子的形式與含氧負離子（如[[碘酸]]和[[重鉻酸]]離子等）形成鹽。{{sfn|Zuckerman|Hagen|1989|pp=190–191}}{{sfn|Kugler|Keller|1985|p=219}}

砹可以和其他[[氧族元素]]成鍵，如和[[硫]]形成S<sub>7</sub>At<sup>+</sup>、{{chem|At(CSN)|2|-}}，和[[硒]]形成[[硒脲]]配合物，以及和[[碲]]形成砹﹣碲[[膠體]]。{{sfn|Zuckerman|Hagen|1989|pp=192–193}}另外，砹在適當條件下，還會與[[氮]]、{{sfn|Zuckerman|Hagen|1989|p=276}}[[鉛]]{{sfn|Zuckerman|Hagen|1989|p=426}}和[[硼]]<ref>{{cite book|title=Contemporary boron chemistry|first=Matthew|last=Davidson|page=146|publisher=Royal Society of Chemistry|year=2000 | isbn = 978-0-85404-835-9 |url = http://books.google.com/books?id=XWgD4uO1VCMC&lpg=PA145&vq=astatine&pg=PA146#v=snippet&q=astatine&f=false}}</ref>鍵合。

已知的有機砹化合物包括四砹化碳（CAt<sub>4</sub>）。<ref name="Emsley"/>砹可以替換[[苯]]中的一個氫原子，形成C<sub>6</sub>H<sub>5</sub>At，氯可以再將其氧化為C<sub>6</sub>H<sub>5</sub>AtCl<sub>2</sub>。該化合物在鹼性次氯酸鹽溶液中會轉化為C<sub>6</sub>H<sub>5</sub>AtO<sub>2</sub>。{{sfn|Zuckerman|Hagen|1989|pp=190–191}}

==歷史==

[[File:Mendelejevs periodiska system 1871.png|thumb|left|300px|門捷列夫1871年的元素表，其中碘以下的位置為空格]]

1869年[[德米特里·門捷列夫]]所發表的[[元素週期表]]中，碘以下的位置為空格。在[[尼爾斯·玻爾]]確立了化學元素分類的物理基礎後，確定第五個鹵素應該在碘以下。在正式發現之前，這一元素被稱為[[eka]]-碘（eka在[[梵文]]中意為「一」），就是「碘之下一格」的意思。<ref>{{cite book|last=Ball|first=Philip|title=The Ingredients: A Guided Tour of the Elements|publisher=Oxford University Press|year=2002|pages=100–102 | isbn = 978-0-19-284100-1 }}</ref>多人嘗試在自然中尋找該元素，但由於其含量極為稀少，許多人的發現都是錯誤的。{{sfn|Lavrukhina|Pozdnyakov|1966|p=226}}

美國阿拉巴馬理工學院（今[[奧本大學]]）的弗雷德·艾利森（Fred Allison）等人在1931年首次聲稱發現85號元素。他們將該元素命名為「alabamine」，符號Ab，以紀念學院所在地[[阿拉巴馬州]]。科學界在其後的幾年中都使用這一名稱。<ref>{{cite journal | title = Evidence of the detection of element 85 in certain substances| first1 = Fred | last1 =Allison | authorlink1=Fred Allison| first2 = Edgar J | last2 =Murphy| first3 = Edna R. | last3 =Bishop| first4 = Anna L. | last4 =Sommer | journal = Physical Reviews | volume = 37 | pages = 1178–1180 | year = 1931 | doi = 10.1103/PhysRev.37.1178 | issue = 9 |bibcode = 1931PhRv...37.1178A }} {{subscription required}}</ref><ref>{{cite journal | url = http://www.time.com/time/magazine/article/0,9171,743159,00.html | title = Alabamine & Virginium | journal=Time Magazine | publisher =Time |accessdate =10 July 2008 | date=15 February 1932}}</ref><ref>{{cite journal | title = What happened to alabamine, virginium, and illinium? | last= Trimble | first = R. F. | journal = Journal of Chemical Education | volume = 52 | page = 585 | year = 1975 | doi =10.1021/ed052p585 | issue = 9 |bibcode = 1975JChEd..52..585T }} {{subscription required}}</ref>然而在1934年，[[伯克利加州大學]]的H·G·麥克弗森（H. G. MacPherson）推翻了艾利森的實驗方法的有效性。<ref>{{cite journal| last = MacPherson| first = H. G.| title = An investigation of the magneto-optic method of chemical analysis| journal = Physical Review| volume = 47| issue = 4| pages = 310–315| publisher = American Physical Society|year=1934|doi = 10.1103/PhysRev.47.310|bibcode = 1935PhRv...47..310M }}</ref>1937年，[[英屬印度]][[達卡]]（今[[孟加拉]]達卡市）的化學家拉真達拉·德（Rajendralal De）也同樣錯誤發現85號元素。他將其命名為「dakin」，並表示它是[[衰變鏈|釷衰變系]]中與鐳F（即釙-210）對等的核素。他的報告中關於這一元素的數據並不符合砹的屬性，而至今dakin究竟是甚麼仍不得而知。<ref>{{cite book | first=Joseph William | last=Mellor | authorlink=Joseph William Mellor | title=A comprehensive treatise on inorganic and theoretical chemistry | publisher=Longmans, Green | year=1965 | oclc=13842122 | page=1066 | url = http://www.archive.org/details/comprehensivetre00mellrich }}</ref>

[[File:Segre.jpg|thumb|right|150px|砹的發現者之一埃米利奧·塞格雷]]

1940年，[[瑞士]]化學家瓦爾特·敏德（Walter Minder）宣佈在鐳A（即釙-218）的[[β衰變]]產物中發現第85號元素，並以瑞士的[[拉丁文]]名稱「{{lang|la|Helvetia}}」將該元素命名為「helvetium」。不過，貝爾塔·卡爾利克（Berta Karlik）和特羅德·貝爾奈（Traude Bernert）無法重現實驗的結果，因此推論敏德實驗所用的氡氣受到了污染（氡-222是釙-218的母同位素）。<ref>{{cite journal | doi = 10.1007/BF01487965 | language= German | title = Über eine vermutete β-Strahlung des Radium A und die natürliche Existenz des Elementes 85 | trans\_title = About a suspected β-radiation of radium A, and the natural existence of the element 85 | year = 1942 | last1 = Karlik | first1 = Berta | authorlink=Berta Karlik | journal = Naturwissenschaften | volume = 30 | pages = 685–686 | last2 = Bernert | first2 = Traude | issue = 44–45|bibcode = 1942NW.....30..685K }} {{subscription required}}</ref>1942年，敏德與英國科學家愛麗絲·雷-史密斯（Alice Leigh-Smith）合作，宣佈在釷A（即釙-216）的β衰變產物中發現85號元素的另一同位素。他們將其命名為「anglo-helvetium」，其中的「anglo」是英國的意思。<ref>{{cite journal | title = Experimental evidence of the existence of element 85 in the thorium family | authorlink1 = Alice Leigh-Smith | first1 = Alice | last1 = Leigh-Smith | authorlink2 = Walter Minder | first2 = Walter | last2 = Minder | journal = Nature | volume = 150 | pages = 767–768 | year = 1942 | doi = 10.1038/150767a0 | issue = 3817|bibcode = 1942Natur.150..767L }} {{subscription required}}</ref>卡爾利克和貝爾奈同樣無法重現這一結果。<ref name="Ru1968">{{cite journal | doi = 10.1070/RC1968v037n02ABEH001603 | title = Astatine | year = 1968 | last1= Nefedov | first1 = V. D. | journal = Russian Chemical Reviews | volume = 37 | pages = 87–98 | last2 = Norseev | first2 = Yu. V. | last3 = Toropova | first3 = M. A. | last4 = Khalkin | first4 = Vladimir A. | issue = 2|bibcode = 1968RuCRv..37...87N }} {{subscription required}}</ref>

1940年，戴爾·科爾森（Dale R. Corson）、肯尼斯·羅斯·麥肯西（Kenneth Ross MacKenzie）和[[埃米利奧·塞格雷]]終於在伯克利加州大學成功分離出該元素。他們並沒有在自然界中尋找，而是在[[迴旋加速器]]中對[[鉍]]-209進行[[α粒子]]撞擊來合成砹元素（釋放兩個中子後形成砹-211）。<ref>{{cite web|url=http://www.chemicool.com/elements/astatine.html |title=Astatine |publisher=Chemicool.com |date= |accessdate=2013-07-24}}</ref><ref name="wemadeit">{{cite journal | title = Artificially radioactive element 85 | first1 = Dale R. | last1 = Corson | authorlink1=Dale R. Corson | first2 = Kenneth Ross | last2 =MacKenzie | authorlink2=Kenneth Ross MacKenzie | first3 = Emilio | last3 = Segrè | authorlink3=Emilio Segrè | journal = Physical Review | publisher = American Physical Society | volume = 58 | pages = 672–678 | year = 1940 | doi = 10.1103/PhysRev.58.672 | issue = 8|bibcode = 1940PhRv...58..672C }} {{subscription required}}</ref>產物迅速進行放射性衰變，因此發現團隊將其取名為「astatine」，詞源為[[希臘文]]中的「ἄστατος」（ástatos，意為「不穩定」）。<ref name="wemadeit" />三年後，卡爾利克和貝爾奈在自然產生的[[衰變鏈]]中發現了砹元素。<ref>{{cite journal | language = German | title = Eine neue natürliche α-Strahlung | trans\_title = A new natural α-radiation | last1 = Karlik | first1 = Berta | pages = 298–299 | volume = 31 | issue = 25–26 | year = 1943 | journal = Naturwissenschaften | doi = 10.1007/BF01475613 | last2 = Bernert | first2 = Traude|bibcode = 1943NW.....31..298K}} {{subscription required}}</ref><ref>{{cite journal | language = German | title = Das Element 85 in den natürlichen Zerfallsreihen | trans\_title = The element 85 in the natural decay chains |journal = Zeitschrift für Physik | volume = 123 | issue = 1–2 | year = 1943 | doi = 10.1007/BF01375144 | pages = 51–72 | last = Karlik | first = Berta | last2 = Bernert | first2 = Trande |bibcode = 1943ZPhy..123...51K}} {{subscription required}}</ref>此後科學家在一共四個自然衰變鏈中的三個當中發現了砹。<ref>{{cite book |first1=Charles Michael|last1=Lederer|first2=Jack M.|last2=Hollander|first3=Isadore|last3=Perlman |year=1967 |title=Table of Isotopes |edition=Sixth |location=New York |pages=1–657|publisher=[[John Wiley & Sons]]}}</ref>

==同位素==

{{main|砹的同位素}}

砹共有32種已知同位素，原子量為191和193至223。<ref name="ffff" />砹沒有穩定或長壽命的同位素。{{sfn|Lavrukhina|Pozdnyakov|1966|p=232}}

<div style="float: left; margin: 0 1em 0 0; font-size:85%;">

{| class="wikitable sortable"

|+ 砹各同位素的α衰變數據{{efn|表中的質量過剩以能量等量作單位；產物質量過剩是子同位素和α離子的質量過剩之和；α半衰期指忽略α以外的其他衰變模式後的半衰期。}}

! 原子量

! 質量過剩<ref name="ffff" />

! 產物質量過剩<ref name="ffff" />

! 平均α衰變能量

! 半衰期<ref name="ffff" />

! α衰變機率<ref name="ffff" />

! α半衰期

|-

| 207

| −13.243&nbsp;MeV

| −19.116&nbsp;MeV

| 5.873&nbsp;MeV

| 1.80小時

| 8.6%

| 20.9小時

|-

| 208

| −12.491&nbsp;MeV

| −18.243&nbsp;MeV

| 5.752&nbsp;MeV

| 1.63小時

| 0.55%

| 12.3天

|-

| 209

| −12.880&nbsp;MeV

| −18.638&nbsp;MeV

| 5.758&nbsp;MeV

| 5.41小時

| 4.1%

| 5.5天

|-

| 210

| −11.972&nbsp;MeV

| −17.604&nbsp;MeV

| 5.632&nbsp;MeV

| 8.1小時

| 0.175%

| 193天

|-

| 211

| −11.647&nbsp;MeV

| −17.630&nbsp;MeV

| 5.983&nbsp;MeV

| 7.21小時

| 41.8%

| 17.2小時

|-

| 212

| −8.621&nbsp;MeV

| −16.436&nbsp;MeV

| 7.825&nbsp;MeV

| 0.31秒

| ≈100%

| 0.31秒

|-

| 213

| −6.579&nbsp;MeV

| −15.834&nbsp;MeV

| 9.255&nbsp;MeV

| 125納秒

| 100%<!-- {{efn|The alpha probability peak at astatine-213 is because alpha decay produces an isotope that has an unusually stable number of neutrons, 126.}} -->

| 125納秒

|-

| 214

| −3.380&nbsp;MeV

| −12.366&nbsp;MeV

| 8.986&nbsp;MeV

| 558納秒

| 100%

| 558納秒

|-

| 219

| 10.397&nbsp;MeV

| 4.073&nbsp;MeV

| 6.324&nbsp;MeV

| 56秒

| 97%

| 58秒

|-

| 220

| 14.350&nbsp;MeV

| 8.298&nbsp;MeV

| 6.052&nbsp;MeV

| 3.71分鐘

| 8%

| 46.4分鐘

|-

| 221{{efn|尚沒有證據顯示砹-221會進行α衰變，因此其衰變能量和能量過剩都不是測量而得的，而是經理論預測估算的。}}

| 16.810&nbsp;MeV

| 11.244&nbsp;MeV

| 5.566&nbsp;MeV

| 2.3分鐘

| 不進行α衰變

| ∞

|}

</div>

砹共有23種[[同核異構體]]，也就是某同位素的一個或多個[[核子]]處於[[激發態]]時的原子核。同核異構體也可稱為亞穩態，也就是其內部能量比[[基態]]能量高，容易衰變回基態。每種同位素可以擁有多個同核異構體。最穩定的砹同核異構體是砹-202m1，{{efn|「m1」指同位素位於基態以上的最低能量狀態，「m2」指基態以上第二低能量狀態，如此類推。如果只有一種亞穩態，可以省略數字，只寫「m」，如砹-216m。}}半衰期約為3分鐘；最為不穩定的是砹-214m1，半衰期只有265[[納秒]]。<ref name="ffff" />

砹的[[α衰變]]能量符合重元素的規律。{{sfn|Lavrukhina|Pozdnyakov|1966|p=232}}較輕的砹同位素擁有較高的α衰變能量，而能量隨原子核質量的增加而降低。砹-211的能量卻比它前面的同位素高出許多，因為其原子核有126個中子──126是一個[[幻數 (物理學)|幻數]]，即中子殼層都已填滿。雖然砹-211的半衰期與砹-210的相近，但是砹-211的α衰變機率有41.81%，比砹-210的0.18%高出許多。<ref name="ffff" />{{efn|這意味著如果忽略α以外的衰變模式，那麼砹-210的α半衰期有4,628.6小時（128.9天），而砹-211只有17.2小時（0.7天）。因此砹-211的α衰變途徑比砹-210不穩定得多。}}接著的兩種同位素則釋放更多能量。砹-213釋放的能量是所有砹同位素中最高的，所以它也是壽命最短的同位素。{{sfn|Lavrukhina|Pozdnyakov|1966|p=232}}儘管較重的同位素釋放較少能量，但是由於[[β衰變]]（電子發射）機率也隨著提升，所以所有砹同位素都是不穩定的。{{sfn|Lavrukhina|Pozdnyakov|1966|p=232}}早在1950年，科學家就預測砹不擁有任何β穩定的同位素（即不進行β衰變的同位素）。<ref>{{cite book|title=Isotope geology|edition=2nd|publisher=Pergamon Press|page=403|year=1956 | isbn = 978-0-470-70800-2 |first=Kalervo|last=Rankama}}</ref>實驗證明，除了砹-213、214、215和216m以外，所有砹同位素都可進行β衰變。<ref name="ffff" />砹-210及以下同位素進行β<sup>+</sup>衰變（[[正子]]發射），砹-216及以上同位素進行β<sup>−</sup>衰變，砹-212可同時進行這兩種衰變模式，砹-211則進行[[中子捕獲]]。<ref name="ffff" />

最穩定的砹同位素是砹-210，半衰期為8.1小時。該同位素的主要通過β<sup>+</sup>衰變形成壽命較長（相對其他砹同位素而言）的釙-210。一共只有5種砹同位素的半衰期超過1小時（原子量從207到211）。基態最不穩定的同位素是砹-213，半衰期為125納秒。這一同位素會經α衰變形成近乎穩定的鉍-209。<ref name="ffff" />

==自然存量==

[[File:Decay Chain(4n+1, Neptunium Series).svg|thumb|right|150px|鎿衰變系：鎿-237延續下來，中間經過砹-217]]

砹是自然界中最稀有的非[[超鈾元素]]，在地殼中每一時刻只有不到1克的總量。<ref name="Hollerman 2001 423"/>所有在[[地球歷史|地球形成]]時存在的砹元素都早已衰變殆盡了，而今天自然中的砹都是重元素的衰變產物。砹曾經被認為是地球上最稀有的元素，但科學家之後發現高濃度含鈾礦藏裡含有經[[中子捕獲]]產生的超鈾元素[[錇]]，而錇比砹更稀有。<ref name="Emsley">{{cite book|last=Emsley|first=John|title=Nature's Building Blocks: An A-Z Guide to the Elements|edition=New|year=2011|publisher=Oxford University Press|location=New York, NY | isbn = 978-0-19-960563-7 |pages=57–58}}</ref>

自然產生的砹同位素共有6種（砹-214至砹-219）。{{sfn|Lavrukhina|Pozdnyakov|1966|p=231}}它們的[[半衰期]]都很短，所以都只以痕量存在。<ref name="chain">{{cite book|title=Chemistry and Analysis of Radionuclides: Laboratory Techniques and Methodology|publisher=Wiley-VCH|pages=2–3|year=2011 | isbn = 978-3-527-32658-7 |first1=Jukka|last1=Lehto|first2=Xiaolin|last2=Hou}}</ref>沒有數據顯示砹能在[[恒星]]中形成。{{sfn|Lavrukhina|Pozdnyakov|1966|p=230}}

其中四種自然同位素（砹-215、217、218和219）是在自然[[衰變鏈]]中發現的。鍅-223是砹-219的母同位素，其α衰變機率只有0.006%，所以就算和其他砹同位素相比，砹-219同樣極為稀有。然而它的半衰期卻是所有自然砹同位素中最長的（56秒）。<ref name="ffff" />砹-219會衰變成釙-215，再經β衰變形成砹-215，機率只有0.00023%。南北[[美洲]]16公里深的地殼以內，每一時刻只有大約一[[兆]]（萬億）個砹-215原子。<ref>{{cite book | url = http://books.google.com/?id=1RMLAAAAMAAJ&dq=%22Only+a+trillion&q=astatine-215#search\_anchor | title = Only a Trillion| first = Isaac | last = Asimov | authorlink = Isaac Asimov | publisher = Abelard-Schuman | year = 1957 | page = 24}}</ref>砹-218是釙-218的β衰變產物，可在自然中出現。與鍅-223和釙-215一樣，形成砹的途徑並不是主要的衰變途徑。<ref name="chain" />不過，鎿衰變系從鎿-237開始，一直到鍅-221都只有唯一的衰變途徑，而鍅-221也只會衰變成砹-217。<ref name="chain" />

自然同位素[[鏷]]-226、227和228會經三重α衰變產生砹-214、215和216。{{sfn|Lavrukhina|Pozdnyakov|1966|p=231}}但是這些同位素也都非常稀有，所以砹-214至216一般都不被當做是自然同位素。<ref name="MoreAt" /><ref name="Qaaa">{{cite book|title=Advances in inorganic chemistry|page=43|publisher=Academic Press|volume=31 |year=1987|author=Emeléus, Harry Julius | isbn = 978-0-12-023631-2}}</ref>

==合成==

===形成===

<div style="float: left; margin: 0 1em 0 0; font-size: 90%;">

{| class="wikitable"

|+ 對鉍-209進行α撞擊後的可能反應

! 反應

! α粒子能量

|-

| style="text-align:center;"| {{chem|209|83|Bi}} + {{chem|4|2|He}} → {{chem|211|85|At}} + 2 {{chem|1|0|n}}

| style="text-align:center;"| 26 MeV<ref name="Ru1968" />

|-

| style="text-align:center;"| {{chem|209|83|Bi}} + {{chem|4|2|He}} → {{chem|210|85|At}} + 3 {{chem|1|0|n}}

| style="text-align:center;"| 40 MeV<ref name="Ru1968" />

|-

| style="text-align:center;"| {{chem|209|83|Bi}} + {{chem|4|2|He}} → {{chem|209|85|At}} + 4 {{chem|1|0|n}}

| style="text-align:center;"| 60 MeV<ref name="Barton">{{cite journal | title = Radioactivity of astatine isotopes | first = G. W. | last = Barton| year = 1951 | journal = Physical Reviews | volume = 82 | issue = 1 | pages = 13–19 | doi = 10.1103/PhysRev.82.13 | last2 = Ghiorso | first2 = Albert | authorlink2=Albert Ghiorso | last3 = Perlman | first3 = I. |bibcode = 1951PhRv...82...13B }} {{subscription required}}</ref>

|}

</div>

砹的主要生產方法是用高能α粒子對鉍-209進行撞擊。每次的產量十分微少，現今的技術每一生產週期可以產出2&nbsp;[[太拉]][[貝克勒爾]]（即2萬億貝克勒爾），約等於25[[微克]]。<ref name="211A">{{cite book|title=Prostate Cancer Methods and Protocols|first1=Pamela Joan|last1=Russell|first2=Paul|last2=Jackson|first3=Elizabeth Anne|last3=Kingsley|year=1989|page=335|publisher=Humana Press | isbn = 978-0-89603-978-0 | url = http://books.google.com/books?id=K1y6k5bdlWkC&lpg=PA335&vq=astatine&dq=%22Prostate%20Cancer%20Methods%20and%20Protocols%22&pg=PA335#v=snippet&q=astatine&f=false}}</ref>

砹-211是目前唯一一個具有商業用途的砹同位素。<ref>{{cite book|edition=2nd|title=The History and Use of Our Earth's Chemical Elements: A Reference Guide|year=2006|last=Krebs|first=Robert E.|publisher=Greenwood Publishing Group | isbn = 978-0-313-33438-2 | url = http://books.google.com/books?id=yb9xTj72vNAC&lpg=PA259&vq=astatine&dq=%22The%20history%20and%20use%20of%20our%20earth's%20chemical%20elements%3A%20a%20reference%20guide%22&pg=PA257#v=snippet&q=astatine&f=false | pages=257–259}}</ref>首先把鉍金屬[[濺射]]到[[金]]、[[銅]]或[[鋁]]表面上，每平方厘米約含50至100微克。這一鉍層（或是[[氧化鉍]]）再與銅片融合，從而製成核反應的鉍目標體。{{sfn|Lavrukhina|Pozdnyakov|1966|p=234}}目標體在不易反應的[[氮氣]]中存放，<ref name="BiN2">{{cite book|title=Inorganic Chemistry for Undergraduates|first=R. |last=Gopalan |year=2009|page=547|publisher=Universities Press | isbn = 978-81-7371-660-7 | url = http://books.google.com/books?id=Fs4zQ-hNTz8C&lpg=PA492&vq=astatine&dq=%22Inorganic%20Chemistry%20for%20Undergraduates%22&pg=PA547#v=snippet&q=astatine&f=false}}</ref>並以水進行降溫，以避免產生了的砹過早地揮發。{{sfn|Lavrukhina|Pozdnyakov|1966|p=234}}α粒子（氦-4原子核）在如[[迴旋加速器]]等粒子加速器中<ref>{{cite book|title=Targeted Radionuclide Tumor Therapy: Biological Aspects|first1=Torgny |last1=Stigbrand |first2=Jorgen |last2=Carlsson |first3=Gregory P|last3=Adams|year=2008|page=150|publisher=Springer | isbn = 978-1-4020-8695-3 | url = http://books.google.com/books?id=-mT0Lthq\_54C&lpg=PA150&vq=astatine&dq=%22Targeted%20Radionuclide%20Tumor%20Therapy%3A%20Biological%20Aspects%22&pg=PA150#v=snippet&q=astatine&f=false}}</ref>高速撞擊鉍目標。雖然使用的只有一種鉍同位素（鉍-209），但有三種可能發生的核反應，分別形成砹-209、210和211。通過把加速器的最高能量調整在砹-211和砹-210的所需能量之間，科學家能夠選擇性地生產砹-211，並避免其他同位素的形成。{{sfn|Lavrukhina|Pozdnyakov|1966|p=234}}

===分離===

<!-- The technique given below (dry distillation) is the only technique commonly cited as the main one, even though solution distillation or purely chemical methods also exist.{{sfn|Lavrukhina|Pozdnyakov|1966|pp=243–254}}

Astatine is very volatile, though less so than iodine in acidic solutions. Out of such solutions, an iron(II) sulfate/sulfuric acid solution seems the most promising, possibly providing [[distillation]] of up to 90% of the element (85% of the solution distilled).{{sfn|Lavrukhina|Pozdnyakov|1966|p=254}} -->

核反應過後所產生的砹與各種其他元素混雜，因此需要經過分離過程。 {{sfn|Lavrukhina|Pozdnyakov|1966|p=254}}含有砹元素的鉍目標體加熱至270&nbsp;°C，這可氣化所有揮發性放射性同位素。之後溫度提高至800&nbsp;°C。雖然80%的砹會在此溫度下氣化，但鉍也同時開始氣化。{{sfn|Lavrukhina|Pozdnyakov|1966|p=254}}砹的氣化過程在600&nbsp;°C以下速率較慢，但在800&nbsp;°C以上就會迅速從鉍表面上揮發出來。{{efn|砹在較低溫度會和鉍形成不揮發的化合物，但這些化合物在700至800&nbsp;°C時會分解。{{sfn|Lavrukhina|Pozdnyakov|1966|p=254}}}} 氣體凝聚後在水冷鉑表面上收集，再轉移到U形[[石英]]器皿中。石英器皿再加溫至130&nbsp;°C，以移除雜質（一般是釙），然後到500&nbsp;°C。這時氣化了的砹可收集到指形冷凝器中。{{sfn|Lavrukhina|Pozdnyakov|1966|p=254}}這樣得出的純化砹可以用弱硝酸溶液洗出冷凝器，作化學和物理分析等用途。這種方法的砹產量可以達到30%。{{sfn|Lavrukhina|Pozdnyakov|1966|p=254}}

==應用及安全==

<div style="float: right; margin: 2px; font-size: 90%;">

{| class="wikitable"

|+ 幾種含<sup>211</sup>At分子及其應用<ref name="211Att">{{cite book|title=Handbook of Nuclear Chemistry|volume=4|first1=Attila |last1=Vértes |first2=Sándor |last2=Nagy |first3=Zoltán|last3=Klencsár|year=2003|page=337|publisher=Springer | isbn = 978-1-4020-1316-4 | url = http://books.google.com/books?id=0skQvMEa8EYC&lpg=PA337&vq=astatine&dq=Handbook%20of%20Nuclear%20Chemistry&pg=PA337#v=snippet&q=astatine&f=false}}</ref>

! 分子

! 應用

|-

| [<sup>211</sup>At]砹﹣碲膠體

| 隔腔腫瘤<!-- Please do not add fact tags to the table; all (all) info may be seen in the source in the title of the table -->

|-

| 6-[<sup>211</sup>At]砹基-2-甲基-1,4-萘醌醇二磷酸

| [[腺癌]]

|-

| 標有<sup>211</sup>At的亞甲藍

| [[黑色素瘤]]

|-

| 間[<sup>211</sup>At]砹苄基胍

| 神經內分泌腫瘤

|-

| 5-[<sup>211</sup>At]砹-2'-脫氧尿苷

| 多用途

|-

| 標有<sup>211</sup>At的生物素結合物

| 各種預定位

|-

| 標有<sup>211</sup>At的奧曲肽

| [[生長抑素受體]]

|-

| 標有<sup>211</sup>At的單株抗體和碎片

| 多用途

|-

| 標有<sup>211</sup>At的類藥物

| [[骨轉移]]

|}

</div>

砹-211具有[[核醫學]]應用。<ref name="211Att" />剛製成的砹需要馬上使用，因為在7.2小時之後，其總量就會減半。砹-211會釋放α粒子，或經[[電子捕獲]]衰變成釋放α粒子的釙-211，所以可用於α粒子[[放射性療法|靶向治療]]。<ref name="211Att" />

砹和碘一樣會積聚在[[甲狀腺]]，但程度較低。如果釋入全身循環，砹會以放射性膠體的形式累積在[[肝臟]]當中。{{sfn|Lavrukhina|Pozdnyakov|1966|p=234}}碘-131是另一種用於醫學的放射性同位素。砹-211與它最大的醫用分別在於，碘-131會釋放高能β粒子，而砹-211則不會。β粒子的穿透能力比較重的α粒子強許多：砹-211所釋放的α粒子可在周圍組織穿透約70&nbsp;µm，而碘-131所釋放的β粒子則可穿透約2&nbsp;mm，這是前者的30倍左右。{{sfn|Lavrukhina|Pozdnyakov|1966|p=234}}因此使用-211可以對甲狀腺施以適量的放射性治療，但同時不足以破壞鄰近的[[副甲狀腺]]組織。由於半衰期更短，穿透能力也較弱，所以砹一般比碘-131更加適合作放射性診斷。{{sfn|Lavrukhina|Pozdnyakov|1966|p=234}}

然而，在老鼠和猴子身上進行的實驗指出，砹對甲狀腺的破壞比碘-131大得多。重複注射砹會造成腺體壞死和[[異型增生]]。這些實驗也顯示，砹可以對任何生物的甲狀腺造成損壞。<ref name="1988At">{{cite journal | doi = 10.1177/096032718800700602 | title = Toxicity of Astatine-211 in the Mouse | year = 1988 | month = November | last1 = Cobb | first1 = L. M. | journal = Human & Experimental Toxicology | volume = 7 | pages = 529–534 | last2 = Harrison | first2 = A. | last3 = Butler | first3 = S. A. | issue = 6}} {{subscription required}}</ref>早期研究還指出，注射致命量的砹還會使乳房組織的形態進行變化，{{sfn|Lavrukhina|Pozdnyakov|1966|p=235}}不過這一結論仍具爭議。<ref name="1988At"/>

==備註==

{{reflist|2|group=註}}

==參考資料==

{{reflist|2}}

==書目==

\* {{cite book | series = Gmelin handbook of inorganic and organometallic chemistry | title = 'At, Astatine', system no. 8a | edition=8th | year = 1985 | publisher = Springer-Verlag | isbn = 3-540-93516-9 | last1 = Kugler | first1 = H. K. | last2 = Keller | first2 = C. | volume = 8 | ref = harv }}

\* {{cite book | language = Russian | title = Аналитическая химия технеция, прометия, астатина и франция | trans\_title = Analytical Chemistry of Technetium, Promethium, Astatine, and Francium | first1 = A. K. | last1 = Lavrukhina | first2 = A. A. | last2 = Pozdnyakov | year = 1966 | publisher = [[Nauka (publisher)|Nauka]] | ref = harv }}

\* {{cite book | title = Inorganic Reactions and Methods, the Formation of Bonds to Halogens | first1 = J. J. | last1 = Zuckerman | first2 = A. P. | last2 = Hagen | year = 1989 | publisher = [[John Wiley & Sons]] | isbn = 978-0-471-18656-4 | ref = harv }}

==外部鏈接==

\* [http://www.periodicvideos.com/videos/085.htm Astatine] at ''The Periodic Table of Videos''（諾丁漢大學）

{{元素週期表}}

[[Category:砹|\*]]

[[Category:卤素]]

[[Category:类金属]]

[[Category:第6周期元素|6e]]

[[Category:化学元素|6e]]

{{Link GA|en}}