新元素和新核素研究进展

任中洲

同济大学 物理科学与工程学院

- 重元素研究的历史
- 超重核实验研究的新进展
- 超重核理论研究状况
- **Z=118**元素合成和新元素命名

周期表(1869)：Q1,门捷列夫未获 Nobel Prize Why?
Q2,与现代周期表差别？Q3,?意义

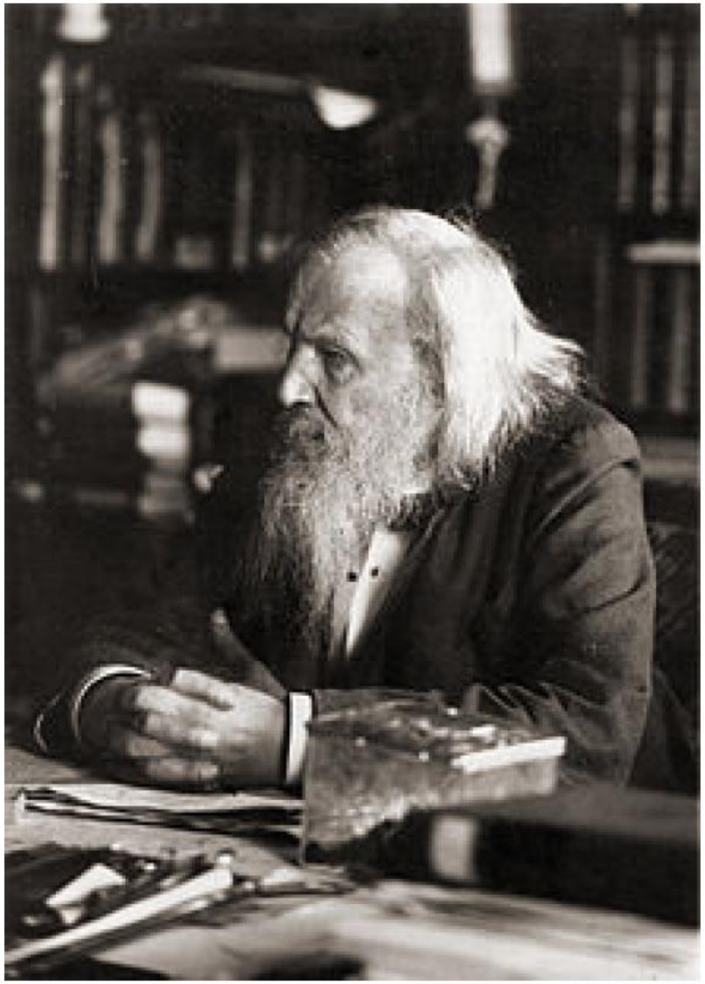
ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ
ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ

			Ti = 50	Zr = 90	? = 180
			V = 51	Nb = 94	Ta = 182
			Cr = 52	Mo = 96	W = 186
			Mn = 55	Rh = 104.4	Pt = 197.4
			Fe = 56	Rn = 104.4	Ir = 198
			Ni = Co = 59	Pl = 106.6	Os = 199
H = 1			Cu = 63.4	Ag = 108	Hg = 200
	Be = 9.4		Mg = 24	Zn = 65.2	Cd = 112
	B = 11	Al = 27.4	? = 68	Ur = 116	Au = 197?
	C = 12	Si = 28	? = 70	Sn = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
	O = 16	S = 32	Se = 79.4	Ta = 128?	
	F = 19	Cl = 35.5	Br = 80	J = 127	
Li = 7	Na = 23	K = 39	Rb = 85.4	Cs = 133	Ti = 204
		Ca = 40	Sr = 87.6	Ba = 137	Pb = 207
		? = 45	Ce = 92		
		?Er = 56	La = 94		
		?Yt = 60	Di = 95		
		?In = 75.6	Th = 118?		

Д. Менделѣевъ

门捷列夫元素周期表初稿(1869 年)

Dmitri Mendeleev



Dmitri Mendeleev in 1897

门捷列夫：1834-1907

钔：Z=101 （Mendelevium）

Born	Dmitri Ivanovich Mendeleev 8 February 1834 Verkhnie Aremzyani, Tobolsk Governorate, Russian Empire
Died	2 February 1907 (aged 72) Saint Petersburg, Russian Empire
Nationality	Russian
Fields	Chemistry, physics and adjacent fields

诺贝尔物理奖，化学奖等

Year	Physics	Chemistry	Physiology or Medicine
1901	W.C. Röntgen (G)	J.H. van't Hoff (NL)	E.A. von Behring (G)
1902	H.A. Lorentz (NL) P. Zeeman (NL)	H.E. Fischer (G)	R. Ross (GB)
1903	A.H. Becquerel (F) P. Curie (F) M. Curie (F)	S.A. Arrhenius (Swe)	N.R. Finsen (D)
1904	J.W.S. Rayleigh (GB)	W. Ramsey (GB)	I.P. Pavlov (R)
1905	P.E.A. von Lenard (G)	J.F.W.A. von Baeyer (G)	R. Koch (G)
1906	J.J. Thomson (GB)	H. Moissan (F)	C. Golgi (I) S. Ramón y Cajal (Sp)
1907	A.A. Michelson (US)	E. Buchner (G)	C.L.A. Laveran (F)
1908	G. Lippman (F)	E. Rutherford (GB)	I.I. Mechnikov (R) P. Ehrlich (G)
1909	G. Marconi (I) C.F. Braun (G)	W. Ostwald (G)	E.T. Kocher (Swi)
1910	J. D. van der Waals (NL)	O. Wallach (G)	A. Kossel (G)
1911	W. Wien (G)	M. Curie (F)	A. Gullstrand (Swe)
1912	N.G. Dalén (Swe)	V. Grignard (F) P. Sabatier (F)	A. Carrel (F)
1913	H. Kamerlingh-Onnes (NL)	A. Werner (Swi)	C.R. Richet (F)
1914	M. von Laue (G)	T.W. Richards (US)	R. Bárány (Au)
1915	W.H. Bragg (GB) L.W. Bragg (GB)	R.M. Willstätter (G)	Not awarded
1916	Not awarded	Not awarded	Not awarded
1917	C.G. Barkla (GB)	Not awarded	Not awarded

WebElements: the periodic table on the world-wide web

http://www.webelements.com/

周期表 (2000)

Key: element name / atomic number / element symbol / 1997 atomic weight (mean relative mass)

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
hydrogen 1 **H** 1.00794(7)																		helium 2 **He** 4.002602(2)
lithium 3 **Li** 6.941(2)	beryllium 4 **Be** 9.012182(3)												boron 5 **B** 10.811(7)	carbon 6 **C** 12.0107(8)	nitrogen 7 **N** 14.00674(7)	oxygen 8 **O** 15.9994(3)	fluorine 9 **F** 18.9984032(5)	neon 10 **Ne** 20.1797(6)
sodium 11 **Na** 22.989770(2)	magnesium 12 **Mg** 24.3050(6)												aluminium 13 **Al** 26.981538(2)	silicon 14 **Si** 28.0855(3)	phosphorus 15 **P** 30.973761(2)	sulfur 16 **S** 32.066(6)	chlorine 17 **Cl** 35.4527(9)	argon 18 **Ar** 39.948(1)
potassium 19 **K** 39.0983(1)	calcium 20 **Ca** 40.078(4)		scandium 21 **Sc** 44.955910(8)	titanium 22 **Ti** 47.867(1)	vanadium 23 **V** 50.9415(1)	chromium 24 **Cr** 51.9961(6)	manganese 25 **Mn** 54.938049(9)	iron 26 **Fe** 55.845(2)	cobalt 27 **Co** 58.933200(9)	nickel 28 **Ni** 58.6934(2)	copper 29 **Cu** 63.546(3)	zinc 30 **Zn** 65.39(2)	gallium 31 **Ga** 69.723(1)	germanium 32 **Ge** 72.61(2)	arsenic 33 **As** 74.92160(2)	selenium 34 **Se** 78.96(3)	bromine 35 **Br** 79.904(1)	krypton 36 **Kr** 83.80(1)
rubidium 37 **Rb** 85.4678(3)	strontium 38 **Sr** 87.62(1)		yttrium 39 **Y** 88.90585(2)	zirconium 40 **Zr** 91.224(2)	niobium 41 **Nb** 92.90638(2)	molybdenum 42 **Mo** 95.94(1)	technetium 43 **Tc** [98.9063]	ruthenium 44 **Ru** 101.07(2)	rhodium 45 **Rh** 102.90550(2)	palladium 46 **Pd** 106.42(1)	silver 47 **Ag** 107.8682(2)	cadmium 48 **Cd** 112.411(8)	indium 49 **In** 114.818(3)	tin 50 **Sn** 118.710(7)	antimony 51 **Sb** 121.760(1)	tellurium 52 **Te** 127.60(3)	iodine 53 **I** 126.90447(3)	xenon 54 **Xe** 131.29(2)
caesium 55 **Cs** 132.90545(2)	barium 56 **Ba** 137.327(7)	57-70 *	lutetium 71 **Lu** 174.967(1)	hafnium 72 **Hf** 178.49(2)	tantalum 73 **Ta** 180.9479(1)	tungsten 74 **W** 183.84(1)	rhenium 75 **Re** 186.207(1)	osmium 76 **Os** 190.23(3)	iridium 77 **Ir** 192.217(3)	platinum 78 **Pt** 195.078(2)	gold 79 **Au** 196.96655(2)	mercury 80 **Hg** 200.59(2)	thallium 81 **Tl** 204.3833(2)	lead 82 **Pb** 207.2(1)	bismuth 83 **Bi** 208.98038(2)	polonium 84 **Po** [208.9824]	astatine 85 **At** [209.9871]	radon 86 **Rn** [222.0176]
francium 87 **Fr** [223.0197]	radium 88 **Ra** [226.0254]	89-102 **	lawrencium 103 **Lr** [262.110]	rutherfordium 104 **Rf** [261.1089]	dubnium 105 **Db** [262.1144]	seaborgium 106 **Sg** [263.1186]	bohrium 107 **Bh** [264.12]	hassium 108 **Hs** [265.1306]	meitnerium 109 **Mt** [268]	ununnilium 110 **Uun** [269]	unununium 111 **Uuu** [272]	ununbium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]		ununhexium 116 **Uuh** [289]		ununoctium 118 **Uuo** [293]

GSI　　Dubna　　Berkeley

*lanthanides	lanthanum 57 **La** 138.9055(2)	cerium 58 **Ce** 140.116(1)	praseodymium 59 **Pr** 140.90765(2)	neodymium 60 **Nd** 144.24(3)	promethium 61 **Pm** [144.9127]	samarium 62 **Sm** 150.36(3)	europium 63 **Eu** 151.964(1)	gadolinium 64 **Gd** 157.25(3)	terbium 65 **Tb** 158.92534(2)	dysprosium 66 **Dy** 162.50(3)	holmium 67 **Ho** 164.93032(2)	erbium 68 **Er** 167.26(3)	thulium 69 **Tm** 168.93421(2)	ytterbium 70 **Yb** 173.04(3)
**actinides	actinium 89 **Ac** [227.0277]	thorium 90 **Th** 232.0381(1)	protactinium 91 **Pa** 231.03588(2)	uranium 92 **U** 238.0289(1)	neptunium 93 **Np** [237.0482]	plutonium 94 **Pu** [244.0642]	americium 95 **Am** [243.0614]	curium 96 **Cm** [247.0703]	berkelium 97 **Bk** [247.0703]	californium 98 **Cf** [251.0796]	einsteinium 99 **Es** [252.0830]	fermium 100 **Fm** [257.0951]	mendelevium 101 **Md** [258.0984]	nobelium 102 **No** [259.1011]

Symbols and names: the symbols of the elements, their names, and their spellings are those recommended by IUPAC. After some controversy, the names of elements 101-109 are now confirmed: see Pure & Appl. Chem., 1997, **69**, 2471–2473. Names have not been proposed as yet for the most recently discovered elements 110–112, 114, 116, and 118 so those used here are IUPAC's temporary systematic names: see Pure & Appl. Chem., 1979, **51**, 381–384. In the USA and some other countries, the spellings aluminum and cesium are normal while in the UK and elsewhere the usual spelling is sulphur.
Periodic table organisation: for a justification of the positions of the elements La, Ac, Lu, and Lr in the WebElements periodic table see W.B. Jensen, "The positions of lanthanum (actinium) and lutetium (lawrencium) in the periodic table", J. Chem. Ed., 1982, 59, 634–636.
Group labels: the numeric system (1–18) used here is the current IUPAC convention. For a discussion of this and other common systems see: W.C. Fernelius and W.H. Powell, "Confusion in the periodic table of the elements", J. Chem. Ed., 1982, **59**, 504–508.
Atomic weights (mean relative masses): see Pure & Appl. Chem., 1996, **68**, 2339–2359. These are the IUPAC 1995 values. Elements for which the atomic weight is contained within square brackets have no stable nuclides and are represented by one of the element's more important isotopes. However, the three elements thorium, protactinium, and uranium do have characteristic terrestrial abundances and these are the values quoted. The last significant figure of each value is considered reliable to ±1 except where a larger uncertainty is given in parentheses.

WebElements: the periodic table

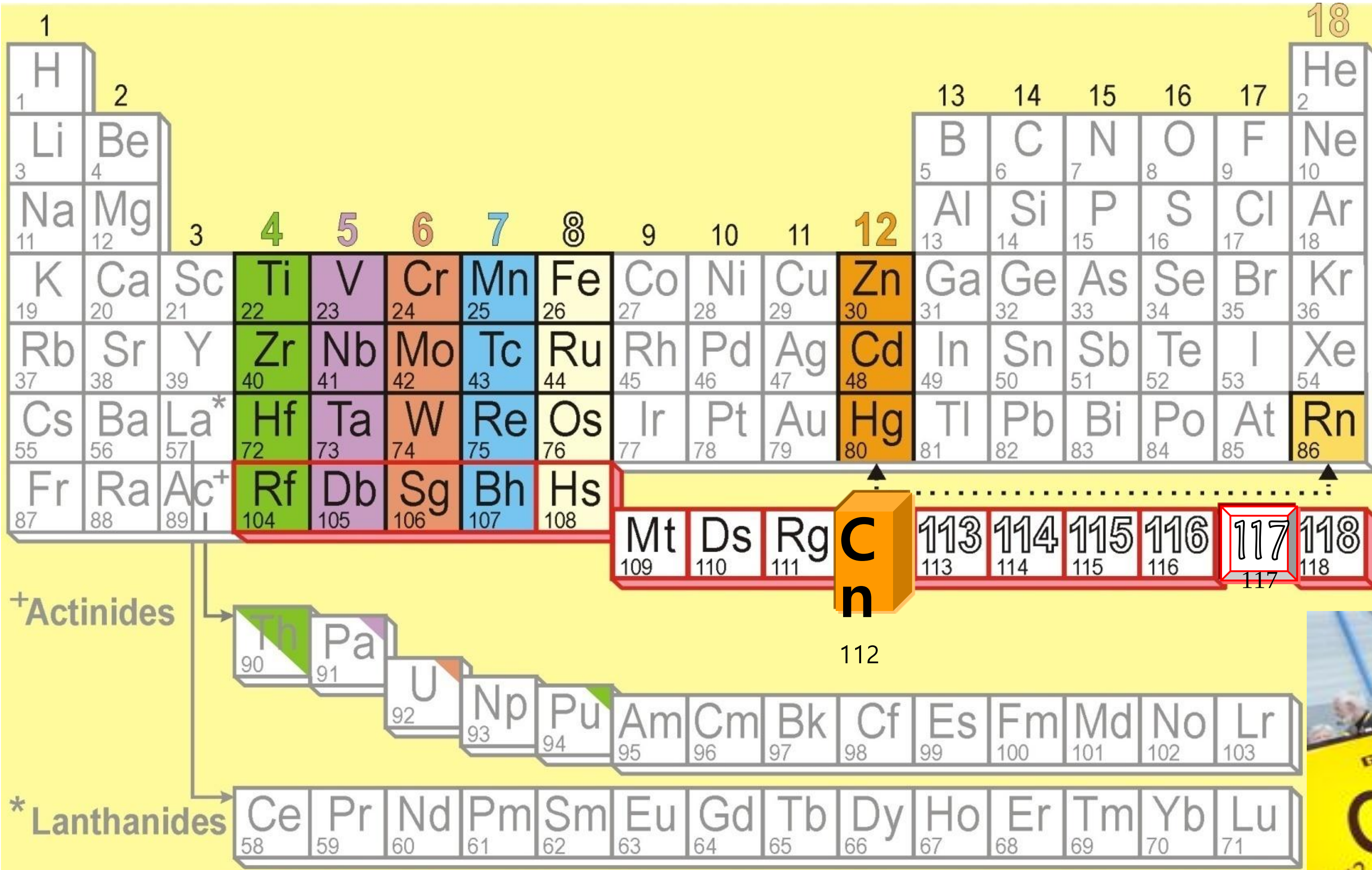
化学元素周期表2008

Group	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																			
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

lawrencium index

*Lanthanoids	*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
**Actinoids	**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

化学元素周期表（Z=112, Cn;　2010)



R. Eichler et al, NATURE, Vol.447(2007)72, *Chemical characterization of element 112*

Oganessian et al., Phys. Rev. Lett. 104, 142502 (2010)

Synthesis of a New Element with Atomic Number Z=117

元素周期表在一直变化：超重新元素的合成和命名

Period	I	II											III	IV	V	VI	VII	VIII
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo

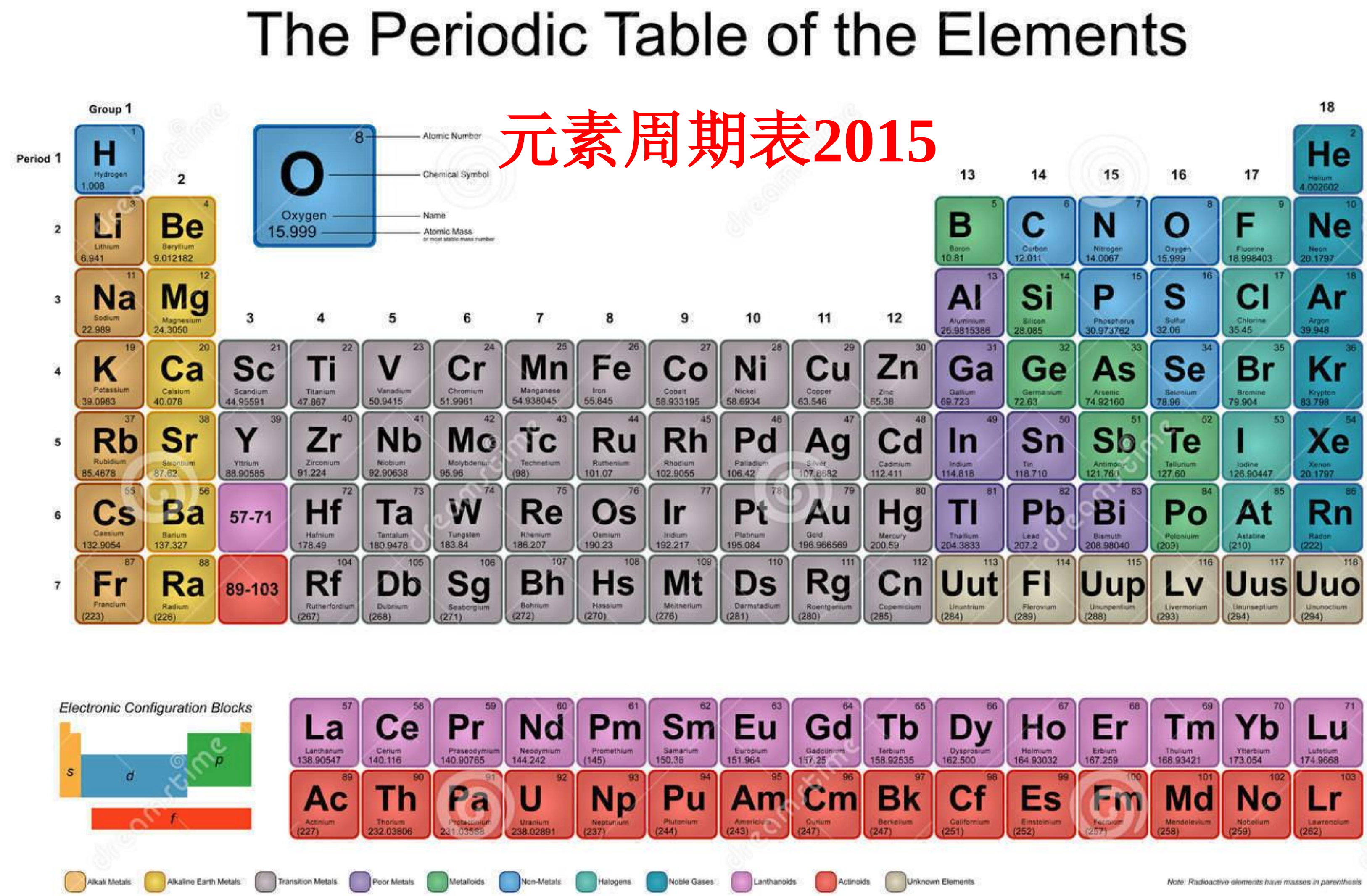
* Lanthanides	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
** Actinides	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

超重原子核：Z>=105，目前实验已经合成到Z=118的新核素。

Z=112以后的核素寿命：μs — min 量级

Uu开头:未命名

元素周期表2015

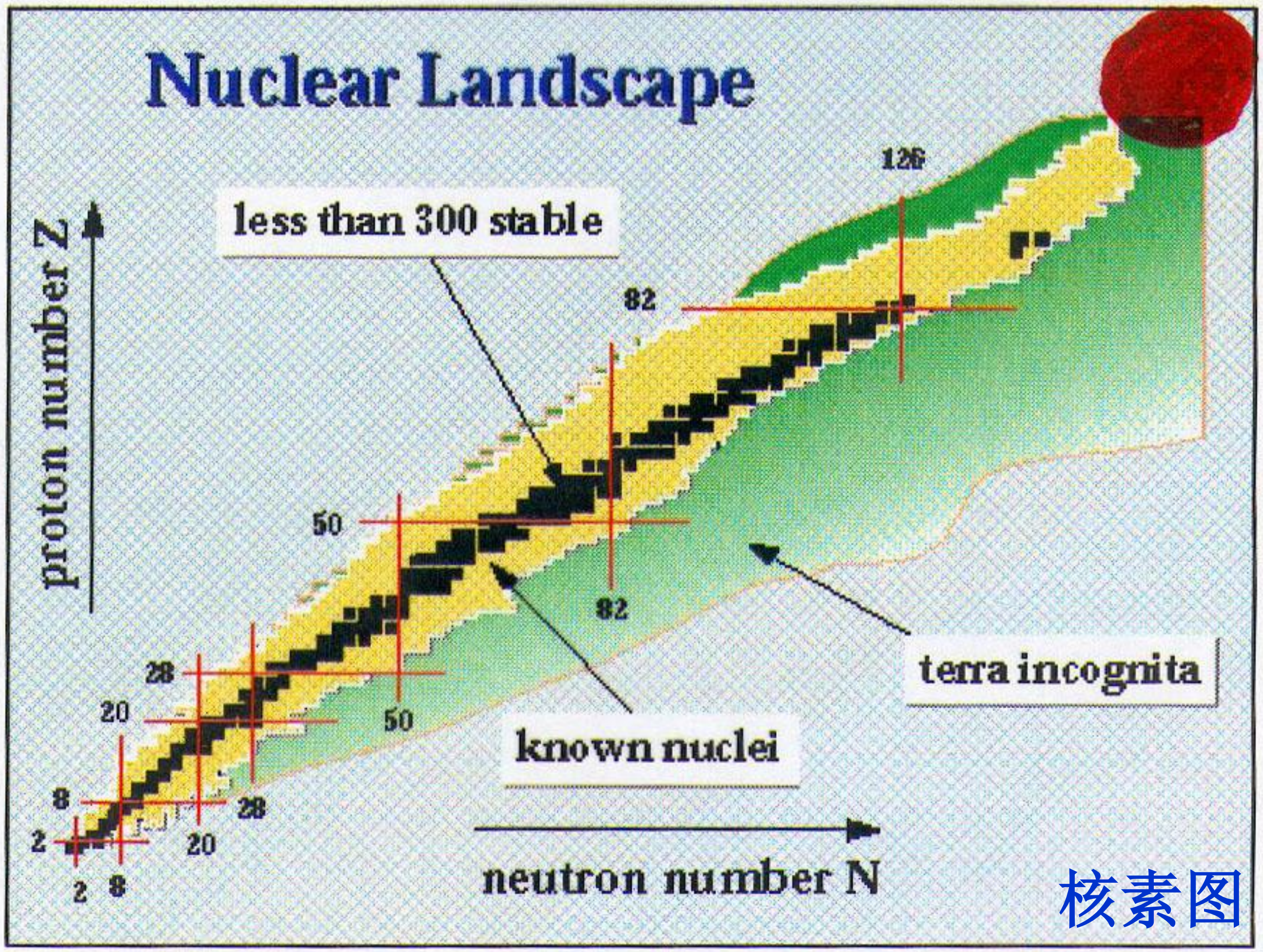

The Periodic Table of the Elements
Group 1
Period 1
Atomic Number
Chemical Symbol
Name
Atomic Mass
Electronic Configuration Blocks
Alkali Metals
Alkaline Earth Metals
Transition Metals
Poor Metals
Metalloids
Non-Metals
Halogens
Noble Gases
Lanthanoids
Actinoids
Unknown Elements
Note: Radioactive elements have masses in parenthesis

最新元素周期表

Group→ ↓Period	1	2	3		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc		22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y		40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 Ac	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

*	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
**	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

近年来研究超重原子核(新元素和新核素）的性质是国际核物理的热点之一.



核素图

1 寻找重元素的历史

- 早期物理学家寻找新化学元素
- 物理学+化学:
- 光谱线: **Fraunhofer, Kirchhoff +Bunsen (Germany): Cs, Rb (37,55); Crookes, Tl(81).**
- 物理学+天文学:
- 日蚀时，观察新光谱线，太阳元素：氦 法国物理学家，英国天文学家（**1868**）.

为什么物理学家介入：物理方法威力大。

1903-1904: Nobel Prize and new elements

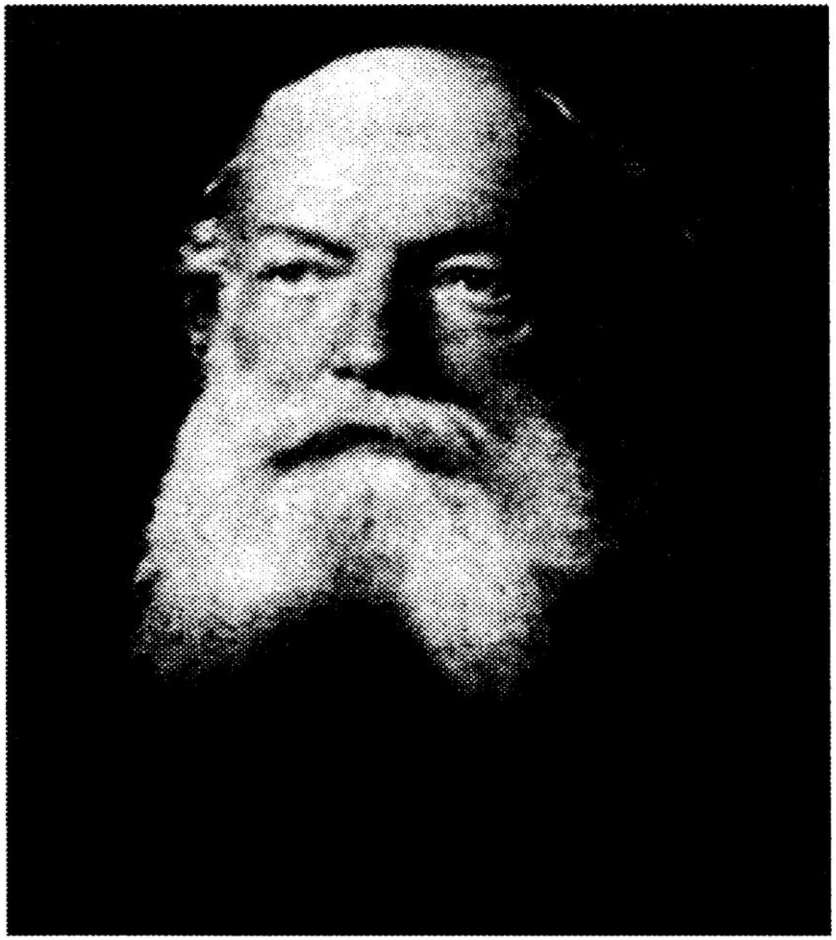
- **1. Rayleigh (physicist: N) +Ramsy (chemist):**
  Ar; He (Crookes: confirm), Ne ,Kr
  1904 Nobel prize (Physics+Chemistry)
- 2. ***M. Curie*** and P. Curie: **Radioactivity;**
  Stronger : new elements, Ra, Po (1898) ?
  1903 Nobel prize (Physics) 1/2+(1/4+1/4)
  1911 Nobel prize (Chemistry) 1/1.
  为什么Curie夫人获两次Nobel奖？

Nobelprize.org
The Official Web Site of the Nobel Prize

Nobel Prizes in Physics

Arguments: Po, Ra (Curie)? Who ?

- 1. A history of physics, Dover Publications, F. Cajori , 1962, USA.
- 2. Une Femme Honorable, Marie Curie;
- De Francoise Giroud;
- Librairie Artheme Fatard, 1981.
- 3. A short history of nearly everything,
- Bill Bryson, Jed Mattes Inc. , 2003



英国物理学家凯尔文爵士

Lord Kelvin

质疑居里夫妇的工作？

1903 物理诺奖？

开尔芬反对蜕变理论

一个引人注目的事件是在1906年8月期间在伦敦《泰晤士报》上关于镭的争论。开尔芬勋爵在英国协会的会议以后立即发起了公开挑战，在这个会议上索迪讨论了元素的演化，并且讲道：铀逐渐地变为镭，镭变为它的射气和几个其他的相继产物，一直到十之八九转变为铅；铅依次逐渐地蜕变成银。[5]开尔芬几乎是单独地对用来解释镭的特性的嬗变和演化学说发动了他的征战。他争辩道：由镭产生氦来证明嬗变并不比在富钇复铀矿中发现氦来证明嬗变更有力些。而假定在

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① *Nature*, Vol.68, 1903.611.

② *Nature*, Vol.70, 1904.107.

③ *Nature*, Vol.70, 1904.516.

④ *Nature*, Vol.70, 1904.241.

⑤ *Nature*, Vol.74, 1906.453.

镭和富钇复铀矿中都含有氦，这就完全足够了。开尔芬否定有实验证据可以证明太阳的热是由于镭的缘故；他把这个热归之于引力。参加这场论战的人当中有洛奇、阿姆斯特朗、斯特劳特和伊夫(Eve)。[①] 开尔芬引证卢瑟福把镭看做化合物的说法并且提出镭可能是由一个铅原子和四个氦原子组成的。索迪又引用卢瑟福的话，只要有一个不跟蜕变理论一致的实验事实被确立下来，就立即放弃它。开尔芬在 1907 年 8 月英国协会上对嬗变理论又发起了论战。他认为，许多化学元素的所有不同的化学的和其他的性质能仅仅用完全相同和类似的初始原子在组合上的差别来解释是几乎不可能的。在同一个会议上，卢瑟福表示的意见是，电子已经变成关键，虽然在那时不可能决定的是，电子在放射现象中释放的或者是由原子的光学性质所揭示的是否仅是原子的外部壳层或原子内核的内部结构的一种显示。

开尔芬的死[2]

几个月以后，在 1907 年 12 月 17 日，开尔芬勋爵离开了人间，终年 83 岁。他的死是他在他的乡间宅第走廊做实验时着凉所致。开尔芬勋爵(威廉·汤姆逊)于 1824 年出生于爱尔兰的贝尔法斯特，但他是苏格兰人的后裔。他和他的兄弟 J. 汤姆逊曾在格拉斯哥学习，他从那里进入剑桥，并于 1845 年以第二名甲等数学优等生的成绩毕业于剑桥大学。麦克斯韦和 J.J. 汤姆逊都是在剑桥数学甲等优等生竞赛性考试中名列第二的两位第一流的物理学家。威廉·汤姆逊在 22 岁时当上了格拉斯哥大学的自然哲学教授，一直任职到死时为止。由于他的卓越的数学和物理学成就，他在 1866 年被授予爵士位，亦在 1892 年被封为开尔芬勋爵。他受到傅里叶和其他法国数学家的数学物理学的极大影响。正是傅里叶的关于通过固体的热流的数学导致他处理了通过导线的电流的扩散问题，并使他解决了通过大西洋的海底电缆发送信号时所遇到的困难。关于他对实验室指导的热诚，我们在讲到物理实验室的发展时再来讲它。

① *Nature*, Vol. 74, 1906. 516—518. 包括对争论的说明。

② S. P. Thompson, *Life of William Thomson*, London, 1910.

1 寻找新元素的历史

- 周期表中30多个元素由核方法合成
- 1930—1949 找到“失踪”元素
- 重元素（U 以后：Z=93,94?)合成
- 核合成的元素被化学家证实

为什么核合成？ 稀有 或 放射性。

The Nobel Prize in Physics 1938

- Enrico Fermi

- *"for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons".*

Nobelprize.org
The Official Web Site of the Nobel Prize

The Nobel Prize in Chemistry 1951

Edwin Mattison McMillan

Prize share:

Glenn Theodore Seaborg

Prize share:

McMillan and Glenn Theodore Seaborg *"for their discoveries in the chemistry of the transuranium elements"*

Nobelprize.org
The Official Web Site of the Nobel Prize

94号元素发现的论文1941年接受后推迟到1946年发表（^{239}Pu）

Physics
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Focus: *Landmarks*: The *Physical Review*'s Explosive Secret

Published October 26, 2004 | Phys. Rev. Focus **14**, 17 (2004) | DOI: 10.1103/PhysRevFocus.14.17

The Physical Review delayed publishing the 1941 discovery of plutonium–which was used in an atomic bomb–until 1946 because of wartime security concerns.

APS has put the entire Physical Review archive online, back to 1893. Focus Landmarks feature important papers from the archive.

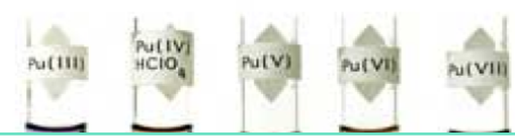
In the early days of World War II, physicists around the world were intently watching the pages of the *Physical Review*, waiting for updates on one of the century's greatest revelations: fission, the splitting of an atom's nucleus accompanied by a prodigious release of energy. But they waited in vain. Because of fears that Germany would use American research to pursue an atomic weapon, the *Physical Review* agreed to withhold reports of significant advances. It was not until several months after an atomic bomb exploded over Nagasaki, Japan, that *Phys. Rev.* published the paper announcing the discovery of plutonium, the material used in that bomb. Physicist Abraham Pais later called the journal's silence on the subject "the most important nonevent in the history of the *Physical Review*."

In 1940 the *Physical Review* published the discovery of element 93, the first element in the periodic table beyond the fissionable element uranium [1]. Although neptunium–named after Uranus's neighbor–was not useful for a bomb, nearly all publication on fission-related work ceased shortly thereafter because of security concerns. The *Physical Review* and hundreds of other scientific journals agreed to submit all articles on the topic to a government committee.

Properties of 94(239)
J. W. Kennedy, G. T. Seaborg, E. Segrè, and A. C. Wahl
Phys. Rev. **70**, 555 (1946)
Published October 1, 1946

Radioactive Element 94 from Deuterons on Uranium
G. T. Seaborg, A. C. Wahl, and J. W. Kennedy
Phys. Rev. **69**, 367 (1946)
Published April 1, 1946

Search for Spontaneous Fission in 94239
Joseph W. Kennedy and Arthur C. Wahl
Phys. Rev. **69**, 367 (1946)
Published April 1, 1946



Element Z=94, Discovered in 1941

Radioactive Element 94 from Deuterons on Uranium

G. T. SEABORG, A. C. WAHL, AND J. W. KENNEDY
Department of Chemistry, Radiation Laboratory, Department of Physics
University of California, Berkeley, California
March 7, 1941*

WE should like to report a few more results which we have found regarding the element 94 alpha-radioactivity formed in the 16-Mev deuteron bombardment of uranium. We sent a first report[1] of this work in a Letter to the Editor of January 28, 1941. We have in the meantime performed more experiments in order to study the chemical behavior of this alpha-radioactive isotope. The radioactivity can be precipitated, in what is probably the +4 valence state, as a fluoride or iodate by using a rare earth or thorium as carrier material and as a peroxyhydrate by using thorium as carrier material. However, in the presence of the extremely strong oxidizing agent persulfate ion ($S_2O_8^{--}$), plus Ag as a catalyst, this radioactive isotope is oxidized to a higher valence state which does not precipitate as a fluoride. The oxidizing agent bromate ion (BrO_3^-) is not sufficiently powerful to oxidize it to this higher valence state and hence the radioactivity comes down as a fluoride even in the presence of bromate

Element Z=94, Published in 1946

ion. With the help of persulfate ion it has been possible to separate quantitatively this radioactivity from thorium, by using the beta-active UX_1 as an indicator for thorium. These experiments make it extremely probable that this alpha-radioactivity is due to an isotope of element 94. The experiments are being continued.

* This letter was received for publication on the date indicated but was voluntarily withheld from publication until the end of the war.

[1] G. T. Seaborg, E. M. McMillan, J. W. Kennedy and A. C. Wahl, Phys. Rev. 69, 366 (1946).

Urey发现氢的同位素氘(新核素)获1934年Nobel化学奖

The Nobel Prize in Chemistry 1934

Harold Clayton Urey

Prize share:

"for his discovery of heavy hydrogen".

Year of discovery (1896-1996)

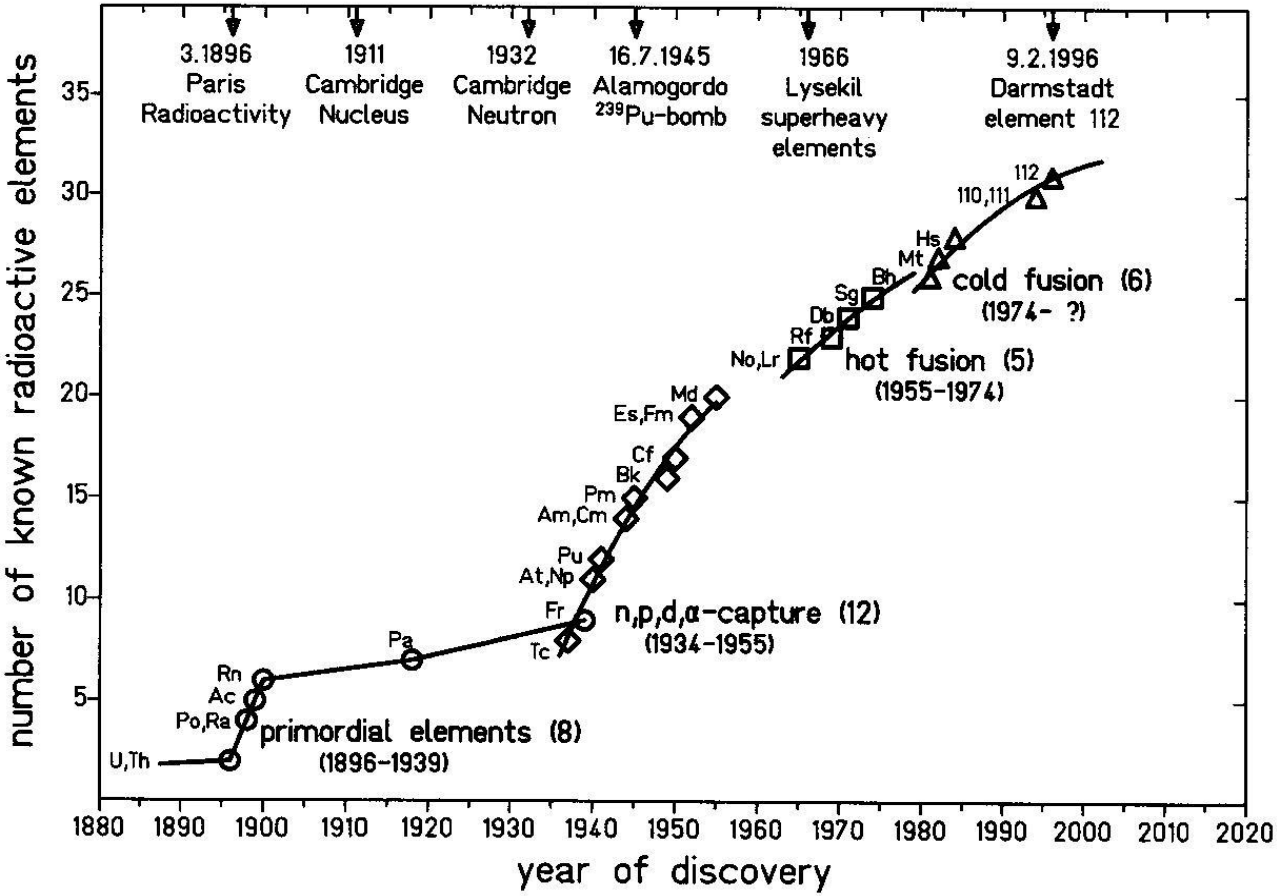


Figure 1 A century of radioactive elements. The number of known radioactive elements as function of time, starting in February 1896 with the discovery of radioactivity in U minerals (1) and ending in February 1996 with the synthesis of element 112 (2).

重元素合成的意义（1）

- 扩展元素周期表
- 到底有多少个化学元素？
- 新元素的应用？超重岛存在？
- 超重岛存在机制？ 新现象？

元素的命名1

Z=101, Md, Mendelevium. (Berkeley).

Z=102, No. Nobelium (Berkeley +Nobel)

Z=103, Lr, Lawrencium. (Berkeley)

Z=104, Rf, Rutherfordium. (Berkeley;Dubna) ?

Z=105, Db, Dubnium (Dubna;Berkeley) ?

Z=106, Sg, Seaborgium. (Dubna;Berkeley) ?

Z=107, Bh, Bohrium (Dubna)

Z=108, Hs, Hassium (GSI; Dubna) ???

Z=109, Mt, Meitnerium (GSI)

Z=110, Ds, Darmstadium…. (GSI)

元素的命名2

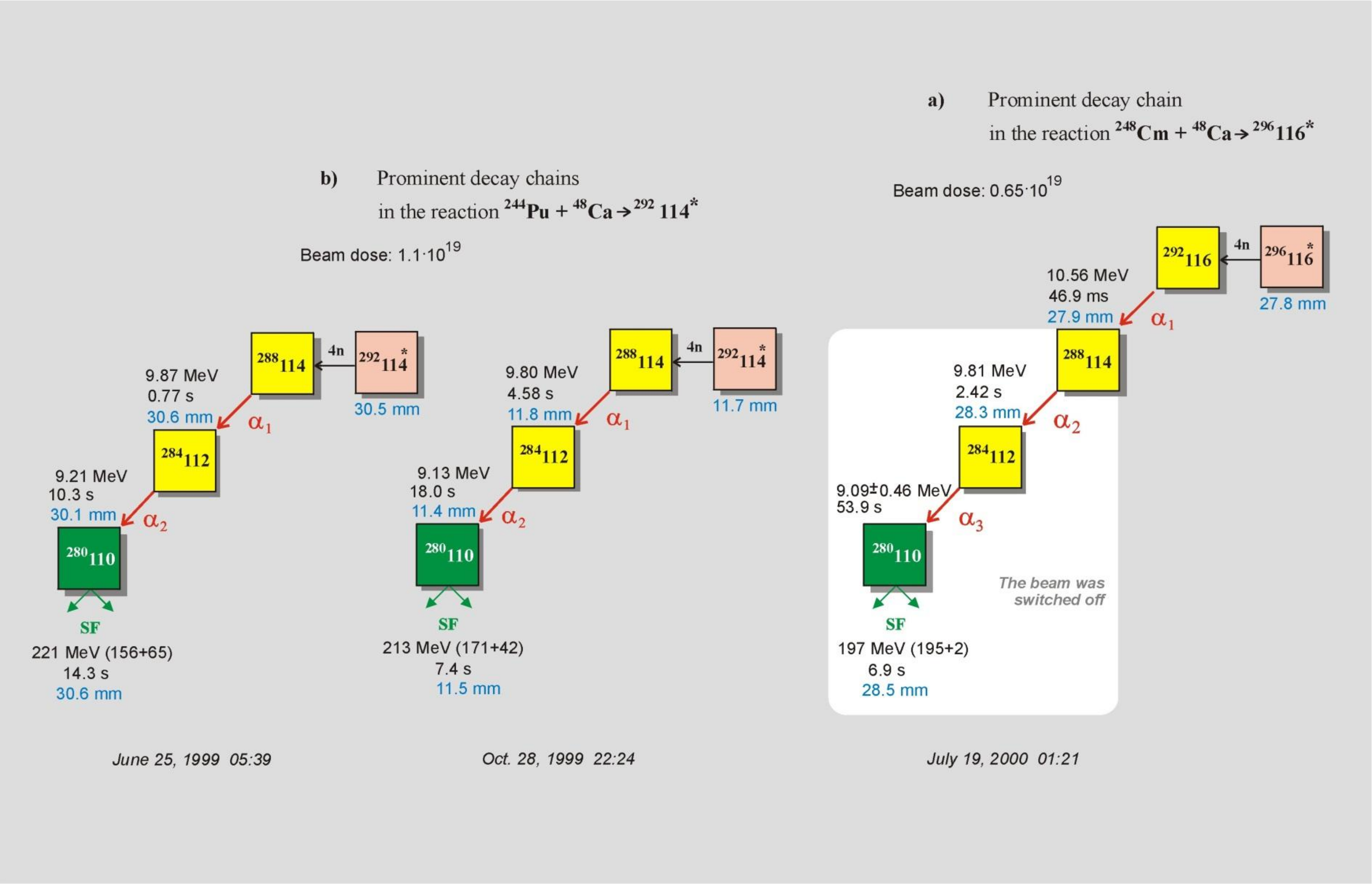
Z=111, Rg, Roentgenium (GSI)

Z=112, Cn, Copernicium (GSI)

Z=114, Fl, Flerovium (Dubna; Livermore)

Z=116, Lv, Livermorium (Dubna; Livermore)

New elements Z=114 and Z=116 (Dubna)



Yuri Oganessian FLNR (JINR) Dubna, July 2000

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Letters to Nature

Nature **400**, 242-245 (15 July 1999) | doi:10.1038/22281; Received 19 April 1999; Accepted 16 June 1999

Synthesis of nuclei of the superheavy element 114 in reactions induced by ^{48}Ca

Yu. Ts. Oganessian[1], A. V. Yeremin[1], A. G. Popeko[1], S. L. Bogomolov[1], G. V. Buklanov[1], M. L. Chelnokov[1], V. I. Chepigin[1], B. N. Gikal[1], V. A. Gorshkov[1], G. G. Gulbekian[1], M. G. Itkis[1], A. P. Kabachenko[1], A. Yu. Lavrentev[1], O. N. Malyshev[1], J. Rohac[1], R. N. Sagaidak[1], S. Hofmann[2], S. Saro[3], G. Giardina[4] & K. Morita[5]

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2. Gesellschaft für Schwerionenforschung, D-64291 Darmstadt, Germany
3. Department of Physics, Comenius University, SK-84215, Bratislava, Slovakia
4. Dipartimento di Fisica dell'Universita di Messina, 98166 Messina, Italy
5. Institute of Physical and Chemical Research (RIKEN), Wako-shi, Saitama, Japan

Correspondence to: A. V. Yeremin[1] Correspondence and requests for materials should be addressed to A.V.Y. (e-mail: Email: eremin@sunvas.jinr.ru).

The stability of heavy nuclides, which tend to decay by α-emission and spontaneous fission, is determined by the structural properties of nuclear matter. Nuclear binding energies and lifetimes increase markedly in the vicinity of closed shells of neutrons or protons (nucleons), corresponding

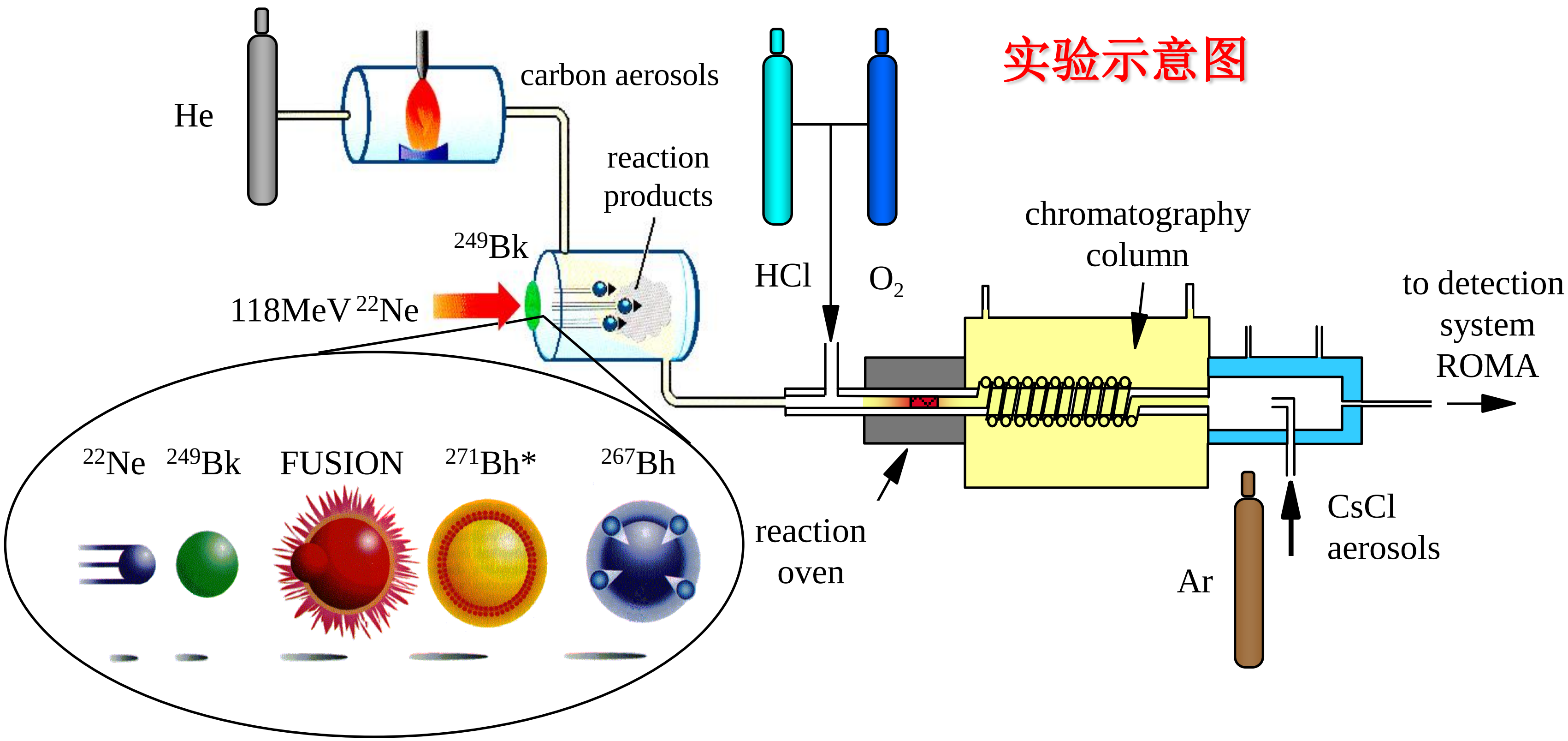
2. Summary of New Results

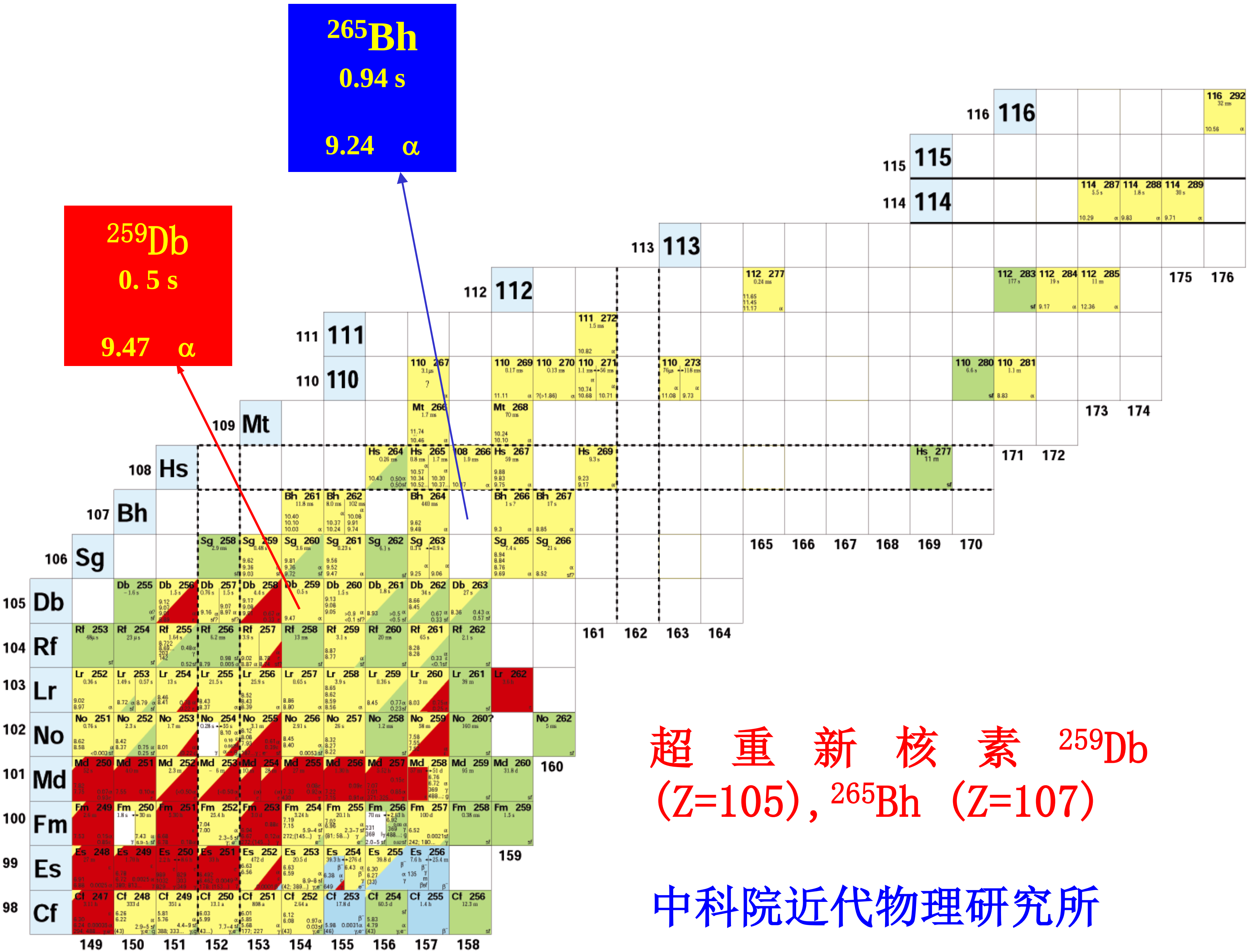
- The elements Z=110-112 were produced at GSI, Hofmann, Muenzenberg…. Z. Phys. A, 1994 -1996.
- Z=114 was synthesized at Dubna by Oganessian et al. Nature, 1999; PRL,1999; PRC, 2000s…
- Z=115 ---118 were produced at Dubna in 2000s—2010s. Oganessian et al, PRC, PRL….
- Z=113, RIKEN; 新核素; Lanzhou: ^{265}107….
- 中国核物理学家之梦：新元素（新装置）

利用核核融合蒸发中子产生新核素

核核碰撞→融合反应→复合核→蒸发中子→新核素

P. A. Wilk et. al PRL 85, 2697 (2000): ^{266}Bh, ^{267}Bh





超 重 新 核 素 ^{259}Db (Z=105), ^{265}Bh (Z=107)

中科院近代物理研究所

国内超重新核素实验^{265}Bh (Z=107), 兰州

Eur. Phys. J. A **20**, 385–387 (2004)

THE EUROPEAN PHYSICAL JOURNAL A

Letter

New isotope ^{265}Bh

Z.G. Gan[1,a], J.S. Guo[1], X.L. Wu[1], Z. Qin[1], H.M. Fan[1], X.G. Lei[1], H.Y. Liu[1], B. Guo[1], H.G. Xu[1], R.F. Chen[1], C.F. Dong[1], F.M. Zhang[1], H.L. Wang[1], C.Y. Xie[1], Z.Q. Feng[1], Y. Zhen[1], L.T. Song[1], P. Luo[1], H.S. Xu[1], X.H. Zhou[1], G.M. Jin[1], and Zhongzhou Ren[2]

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[2] Department of Physics, Nanjing University, Nanjing 210008, PRC

^{265}Bh的实验结果与理论预言一致[12,13]

The derived Q_α from the measured α energy for ^{265}Bh was 9.38 MeV, which was in agreement with the expected Q_α value by Zhongzhou Ren *et al.* [12,13]. The experimental half-life of ^{265}Bh also agrees with the calculations [13] $T_{1/2} = 2.6$

国内新核素实验^{205}Ac (Z=89), 兰州

PHYSICAL REVIEW C **89**, 014308 (2014)

α decay of the new neutron-deficient isotope ^{205}Ac

Z. Y. Zhang (张志远),[1] Z. G. Gan (甘再国),[1,*] L. Ma (马龙),[1,2,3] L. Yu (郁琳),[1,2] H. B. Yang (杨华彬),[1,2,3] T. H. Huang (黄天衡),[1] G. S. Li (李广顺),[1] Y. L. Tian (田玉林),[1] Y. S. Wang (王永生),[1] X. X. Xu (徐新星),[4] X. L. Wu (吴晓蕾),[1] M. H. Huang (黄明辉),[1,5] C. Luo (罗成),[1] Z. Z. Ren (任中洲),[6,7] S. G. Zhou (周善贵),[7,8] X. H. Zhou (周小红),[1] H. S. Xu (徐瑚珊),[1] and G. Q. Xiao (肖国青)[1]

[1]*Key Laboratory of High Precision Nuclear Spectroscopy and Center for Nuclear Matter Science, Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China*
[2]*University of Chinese Academy of Sciences, Beijing 100049, China*
[3]*School of Nuclear Science and Technology, Lanzhou University, Lanzhou 730000, China*
[4]*China Institute of Atomic Energy, Beijing 102413, China*
[5]*Nishina Center for Accelerator-Based Science, RIKEN, Wako, Saitama 351-0198, Japan*
[6]*Department of Physics, Nanjing University, Nanjing 210093, China*
[7]*Center of Theoretical Nuclear Physics, National Laboratory of Heavy-Ion Accelerator, Lanzhou 730000, China*
[8]*State Key Laboratory of Theoretical Physics, Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing 100190, China*

(Received 1 December 2013; published 13 January 2014)

The new neutron-deficient isotope ^{205}Ac was synthesized in the complete-fusion reaction ^{169}Tm(^{40}Ca, $4n$)^{205}Ac. The evaporation residues were separated in-flight by the gas-filled recoil separator SHANS in Lanzhou and subsequently identified by the α-α position and time correlation method. The α-decay energy and half-life of ^{205}Ac were determined to be 7.935(30) MeV and 20^{+97}_{-9} ms, respectively. Previously reported decay properties of the ground state in ^{206}Ac were confirmed.

PRC2014： new nuclide ^{205}Ac

In Refs. [16,17], a new version of the Geiger-Nuttall law including the quantum numbers of α-core relative motion was proposed, which reproduces the α-decay half-lives of heavy nuclei with $N \leqslant 126$ very well. In Fig. 3(b), a calculation using this law is carried out for the favored α-decay transitions, and the results are compared with experimental values. The calculated 15-ms half-life of ^{205}Ac is in good agreement with the value measured in the present experiment.

The calculated half-life (15 ms) with new Geiger-Nuttall law [16,17] agrees well with measured data (20 $^{+97}_{-9}$ms).

[16] Yuejiao Ren and Zhongzhou Ren, Phys. Rev. C **85**, 044608 (2012).
[17] Yuejiao Ren and Zhongzhou Ren, Nucl. Sci. Tech. **24**, 050518 (2013), http://www.j.sinap.ac.cn/nst/EN/Y2013/V24/I5/50518.

New isotope ^{216}U: identified by alpha decay chain:
Ma, Zhang, Gan,..,Ren, Zhou,..PRC 91 (2015) 051302

PHYSICAL REVIEW C **91**, 051302(R) (2015) **RAPID COMMUNICATIONS**

α-decay properties of the new isotope ^{216}U

L. Ma (马龙),[1,2,3] Z. Y. Zhang (张志远),[1] Z. G. Gan (甘再国),[1,*] H. B. Yang (杨华彬),[1,2,3] L. Yu (郁琳),[1,2] J. Jiang (姜舰),[1,2] J. G. Wang (王建国),[1] Y. L. Tian (田玉林),[1] Y. S. Wang (王永生),[1] S. Guo (郭松),[1] B. Ding (丁兵),[1] Z. Z. Ren (任中洲),[4,5] S. G. Zhou (周善贵),[5,6] X. H. Zhou (周小红),[1] H. S. Xu (徐瑚珊),[1] and G. Q. Xiao (肖国青)[1]

The new neutron-deficient isotope ^{216}U was produced in the complete-fusion reaction ^{180}W(^{40}Ar,4n)^{216}U. The evaporation residues were separated from the primary beam in flight by the gas-filled recoil separator Spectrometer for Heavy Atoms and Nuclear Structure. The activities have been identified by the α-α position and time correlation measurements. Two α-decaying states with $E_\alpha = 8384(30)$ keV, $T_{1/2} = 4.72^{+4.72}_{-1.57}$ ms for the ground state and $E_\alpha = 10582(30)$ keV, $T_{1/2} = 0.74^{+1.34}_{-0.29}$ ms for an isomeric state were identified in ^{216}U.

3. theory.

- **J. A. Wheeler et al, 1950s: Superheavy nuclei**
- **P.R., 1958.**

- **Bethe and his collaborator, PRL, 1967.**

- **1960s-1980s, macroscopic-microscopic model (MM): Nilsson et al, Z=114 and N=184 ?**

- **Moeller, Nix, Kratz, At. Dat. Nu. Dat. 1997.**
- **Myers and Swiatecki, PRC, 1998.**

Werner and Wheeler, PR, 1958: superheavy nuclei

PHYSICAL REVIEW · VOLUME 109, NUMBER 1

Superheavy Nuclei

Frederick G. Werner and John A. Wheeler
Palmer Physical Laboratory, Princeton University, Princeton, New Jersey

(Received August 19, 1957)

The semiempirical mass formula and other data previously extrapolated by one of us indicated possible existence of nuclei with mass values up to twice the largest now known. Here this mass region is further explored. Extrapolations are revised and the properties of such superheavy nuclei are estimated in more detail. Despite Z values substantially higher than 137, the K electrons behave perfectly normally because of the finite extension of the nucleus. Vacuum polarization and vacuum fluctuations are roughly estimated to make relatively minor alterations in the K electron binding—which exceeds mc^2. The effect of nuclear attraction in speeding up beta decay is calculated approximately. Calculated beta lives are never much less than 10^{-4} sec. Beta decay energies and neutron binding energies are calculated from the semiempirical mass formula. Fission barriers and cross sections for the (n,γ) process are estimated. Branching ratios in beta decay are calculated for the processes of simple beta decay and for "delayed" neutron emission and "delayed" fission. The latter quantity sets an irreducible minimum to the losses that occur in the process of buildup under even the heaviest neutron flux. The calculated fractional yield of nuclei which reach $Z=147$, $A=500$ is >0.05. Under a lower flux the losses are greater. *All stability calculations in this paper depend upon substantial extrapolations, with complete disregard of shell effects and other particularities that may be important, and therefore can be completely in error.* Conversely, observation of existence or absence of superheavy nuclei with lives less than a second should test stringently the semiempirical mass formula and the semiempirical estimates of spontaneous fission barriers.

Siemens and Bethe: nuclei with Z>104 are prolate

VOLUME 18, NUMBER 17 PHYSICAL REVIEW LETTERS 24 APRIL 1967

SHAPE OF HEAVY NUCLEI*

Philip J. Siemens† and H. A. Bethe
Laboratory of Nuclear Studies, Cornell University, Ithaca, New York
(Received 10 March 1967)

cal mass formula. The configurations investigated were a spherical shell, and oblate and prolate spheroids. It was found that, for beta-stable nuclei with more than 104 protons, the most energetically favorable configuration is a prolate spheroid.

3. Theory (SHF and RMF 1990…)

- **Macroscopic—Microscopic Model (MM model)**
- **Various Mass Formulas and Mass Model**
- **Nonrelativistic Many-body Theory (SHF…)**

- **Relativistic many-body theory (RMF model…)**
- **Nuclear many-body problem: A=4--300**
- **Strong: meson exchanges; Coulomb: photons…**
- **Coupled Dirac-Eqs. and Klein-Gordon Eqs.**

创新点及意义 (1)

- 提出超重核形状共存----可能是超重核存在新机制:
- 改进和发展了数值计算方法和程序
- 完成大规模数值计算
- 提出超重核形状共存, 形变重要, 有低能同质异能态

- 发表了一系列论文(PRC 3篇; NPA 2篇等)
- 论文被国外同行引用和肯定:
- 论文被国际上著名实验小组引用(Dubna-Livemore-PSI)
- 论文被综述文章引用(Nature, PRC, JPG)

Fig. 3 Theoretical and experimental alpha decay energies for GSI Data: Z=110, 111, 112 (+2, +1, 0 shift).

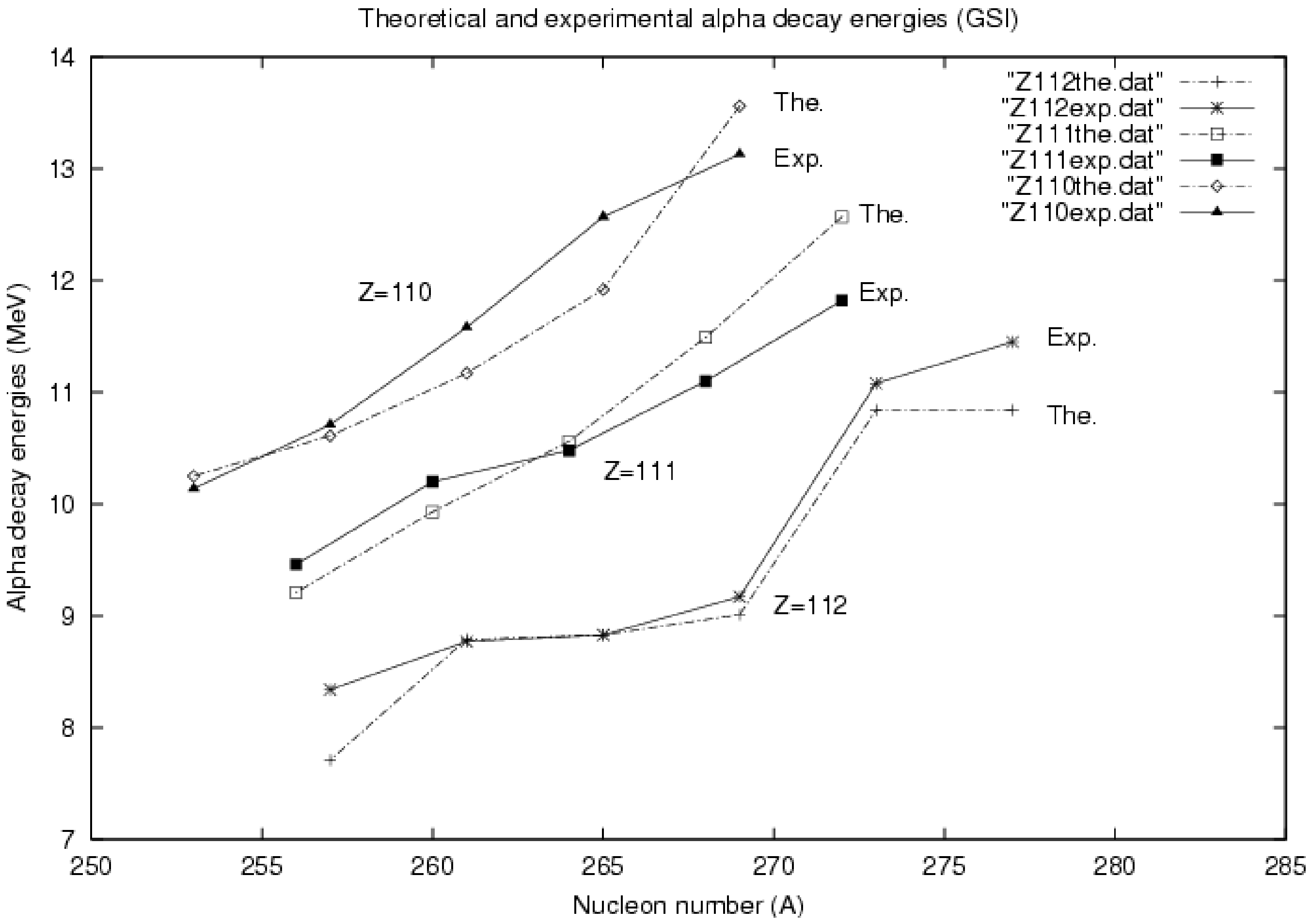

Table 1, RMF results for Cf. (TMA and NLZ2)

Nuclei	$B_{the.}$ (1)	$Beta_p$	$B_{the.}$(2)	$Beta_p$	$B_{exp.}$(MeV)
^{244}Cf	1832.9	0.26	1829.7	0.31	1831.3
^{246}Cf	1846.3	0.27	1843.1	0.31	1844.8
^{248}Cf	1859.0	0.26	1855.5	0.31	1857.8
^{250}Cf	1871.0	0.26	1866.9	0.31	1870.0
^{252}Cf	1882.4	0.26	1877.8	0.31	1881.3
^{254}Cf	1892.9	0.25	1888.5	0.30	1892.1

Experimental deformation $Beta_2$=0.30 for $^{250,252}Cf$

Table 2, RMF results for No. (TMA and NLZ2)

Nuclei	$B_{the.}$ (1)	$Beta_p$	$B_{the.}$(2)	$Beta_p$	$B_{exp.}$(MeV)
^{252}No	1873.2	0.26	1870.7	0.31	1871.3
^{254}No	1887.2	0.27	1884.1	0.31	1885.6
^{256}No	1900.7	0.27	1897.0	0.31	1898.6
^{258}No	1912.9	0.27	1909.6	0.30	1911.1^{audi}
^{260}No	1924.6	0.26	1921.7	0.30	1923.1^{audi}
^{262}No	1935.8	0.21	1933.1	0.29	1934.7^{audi}

Experimental deformation $Beta_2$=0.27 for ^{254}No

Oganessian et al, PRC72 2005

PHYSICAL REVIEW C **72**, 034611 (2005)

Synthesis of elements 115 and 113 in the reaction ^{243}Am + ^{48}Ca

Yu. Ts. Oganessian, V. K. Utyonkov, S. N. Dmitriev, Yu. V. Lobanov, M. G. Itkis, A. N. Polyakov, Yu. S. Tsyganov, A. N. Mezentsev, A. V. Yeremin, A. A. Voinov, E. A. Sokol, G. G. Gulbekian, S. L. Bogomolov, S. Iliev, V. G. Subbotin, A. M. Sukhov, G. V. Buklanov, S. V. Shishkin, V. I. Chepygin, G. K. Vostokin, N. V. Aksenov, M. Hussonnois, K. Subotic, and V. I. Zagrebaev

Joint Institute for Nuclear Research, RU-141980 Dubna, Russian Federation

K. J. Moody, J. B. Patin, J. F. Wild, M. A. Stoyer, N. J. Stoyer, D. A. Shaughnessy, J. M. Kenneally, P. A. Wilk, and R. W. Lougheed

University of California, Lawrence Livermore National Laboratory, Livermore, California 94551, USA

H. W. Gäggeler, D. Schumann, H. Bruchertseifer, and R. Eichler

Paul Scherrer Institute, Villigen CH-5232, Switzerland

(Received 21 March 2005; published 29 September 2005)

The results of two experiments designed to synthesize element 115 isotopes in the ^{243}Am + ^{48}Ca reaction are presented. Two new elements with atomic numbers 113 and 115 were observed for the first time. With 248-MeV ^{48}Ca projectiles, we observed three similar deca

Predictions of SHF and RMF compare well with MM results [12,13]

In our experiments, α-decay properties proposed by the MM nuclear model [6,7] were used for setting the initial experimental parameters. One should note that the predictions of other models within the Skyrme-Hartree-Fock-Bogoliubov (SHFB) and the relativistic mean-field (RMF) approaches compare well with the MM results (see, e.g., [12,13]). Unfortunately, calculations of the probability of spontaneous fission and electron capture for odd nuclei are rather scarce.

[13] Z. Ren *et al.*, Phys. Rev. C **67**, 064302 (2003).

Oganessian et al, PRC72 2005

V. DISCUSSION

The experimental α-decay energies Q_α^{exp} of the synthesized isotopes and previously known odd-Z nuclei with $Z \geqslant 103$ are plotted in Fig. 9(a). The Q_α^{exp} of even-Z nuclei, including those produced in our experiments [1,2,20], are plotted in Fig. 9(b) for comparison. The α-decay energies attributed to the isotopes of Mt and Bh coincide well with theoretical values [7], also plotted in the figures. The same can be seen for the last nuclei in the decay chain ^{275}Hs → ^{271}Sg → ^{267}Rf.

The trend of the $Q_\alpha(N)$ systematics predicted by the MM model [6,7] and confirmed by experimental data for odd-Z isotopes of Mt and Bh along with even-Z isotopes of Ds can

SHF [12, 49-51] and RMF [13, 52-57] compare well with the experimental results

considerable increase in T_α for the new heavier isotopes Db

[54] Z. Ren, Phys. Rev. C **65**, 051304(R) (2002).

[55] S. Das and G. Gangopadhyay, J. Phys. G **30**, 957 (2004).

[56] Z. Ren *et al.*, Phys. Rev. C **67**, 064302 (2003).

For the isotopes ^{279,280}Rg and ^{283,284}113 the difference between theoretical and experimental Q_α values is 0.6–0.9 MeV. Some part of this energy can be accounted for by γ-ray emission from excited levels populated during α decay. For the even-Z nuclei as well, the agreement between theory and experiment becomes somewhat worse as one moves from the deformed nuclei in the vicinity of neutron shells $N = 152$ and $N = 162$ to the more neutron-rich nuclides with $N \geqslant 169$. In this region, experimentally measured values of Q_α are less than the values calculated from the model by $\leqslant$0.5 MeV. Although the predicted Q_α values for the heaviest nuclei observed in our experiments are systematically larger than the experimental data as a whole, the trends of the predictions are in good agreement for the 23 nuclides with $Z = 106$–118 and $N = 165$–177, especially considering that the theoretical predictions of the MM model match the experimental data over a broad previously unexplored region of nuclides.

One should note that the predictions of other models for even-Z and odd-Z nuclei within the Skyrme-Hartree-Fock-Bogoliubov [12,49–51] and the relativistic mean-field [13,52–57] methods also compare well with the experimental results. These models predict the same spherical neutron shell at $N = 184$, but different proton shells, $Z = 114$ (MM) and $Z = 120$, 124, or 126 (SHFB, RMF), yet all describe the experimental data equally well. Such insensitivity with respect

15. Ren, Z. Shape coexistence in even-even superheavy nuclei. Phys. Rev. C65, 051304 (2002)

Cited: shape coexistence, Ref. [15]

Nature, 433 (2005) 705

review article

Shape coexistence and triaxiality in the superheavy nuclei

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*Deceased

Superheavy nuclei represent the limit of nuclear mass and charge; they inhabit the remote corner of the nuclear landscape, whose extent is unknown. The discovery of new elements with atomic numbers $Z \geq 110$ has brought much excitement to the atomic and nuclear physics communities. The existence of such heavy nuclei hangs on a subtle balance between the attractive nuclear force and the disruptive Coulomb repulsion between protons that favours fission. Here we model the interplay between these forces using self-consistent energy density functional theory; our approach accounts for spontaneous breaking of spherical symmetry through the nuclear Jahn–Teller effect. We predict that the long-lived superheavy elements can exist in a variety of shapes, including spherical, axial and triaxial configurations. In some cases, we anticipate the existence of metastable states and shape isomers that can affect decay properties and hence nuclear half-lives.

NATURE | VOL 433 | 17 FEBRUARY 2005

review article

Shape coexistence and triaxiality in the superheavy nuclei

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15. Ren, Z. Shape coexistence in even-even superheavy nuclei.

我们提出了超重核有形状共存现象，形变特别重要的观点。论文受到了在Nature杂志上发表的综述文章引用，其论文题目与我们的题目类似，和我们有相同观点。

PHYSICAL REVIEW C, VOLUME 65, 051304(R)

RAPID COMMUNICATIONS

Shape coexistence in even-even superheavy nuclei

Zhongzhou Ren
Department of Physics, Nanjing University, Nanjing 210008, People's Republic of China
and Center of Theoretical Nuclear Physics, Institute of Modern Physics, Lanzhou 730000, China

配合国内实验, 理论预言：$^{265}107$ Q_a and T_a

Z. Ren et al, PRC 67 (2003) 064302;
JNRS 3 (2002) 195.

^AX	B (MeV)	$Beta_n$	$Beta_p$	Q_a (MeV)	T_a (second)
$^{269}109$	1960.17	0.22	0.23	10.21	0.069
$^{265}107$	1942.08	0.23	0.24	9.41	2.56
$^{261}105$	1923.19	0.26	0.26	9.14	3.33
$^{257}103$	1904.03	0.26	0.27	8.12	$1.28*10^3$

Expt: Gan et al, EPJA 2004, Q_a=9.38 , T_a=0.94 s.
Good agreement between theory and data.

国内超重新核素实验265Bh (Z=107)

Eur. Phys. J. A **20**, 385–387 (2004)

THE EUROPEAN PHYSICAL JOURNAL A

Letter

New isotope ^{265}Bh

Z.G. Gan[1,a], J.S. Guo[1], X.L. Wu[1], Z. Qin[1], H.M. Fan[1], X.G. Lei[1], H.Y. Liu[1], B. Guo[1], H.G. Xu[1], R.F. Chen[1], C.F. Dong[1], F.M. Zhang[1], H.L. Wang[1], C.Y. Xie[1], Z.Q. Feng[1], Y. Zhen[1], L.T. Song[1], P. Luo[1], H.S. Xu[1], X.H. Zhou[1], G.M. Jin[1], and Zhongzhou Ren[2]

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265Bh实验结果与理论预言一致[12,13]

The derived Q_α from the measured α energy for ^{265}Bh was 9.38 MeV, which was in agreement with the expected Q_α value by Zhongzhou Ren *et al.* [12,13]. The experimental half-life of ^{265}Bh also agrees with the calculations [13] $T_{1/2} = 2.6$

4. Synthesis of new element Z=118

1). 2002, Dubna: D7-2002-287. **Exp.**

2). PRC69, 2004 (May).

3). PRC70, 2004 (Dec.).

4). Phys. Scrt. 2006 (June)

5). PRC 74, 2006 (October).

Publication

Oganessian PRC69 (2004): Z=118

PHYSICAL REVIEW C **69**, 054607 (2004)

Measurements of cross sections for the fusion-evaporation reactions $^{244}Pu(^{48}Ca,xn)^{292-x}114$ and $^{245}Cm(^{48}Ca,xn)^{293-x}116$

Yu. Ts. Oganessian, V. K. Utyonkov, Yu. V. Lobanov, F. Sh. Abdullin, A. N. Polyakov, I. V. Shirokovsky, Yu. S. Tsyganov, G. G. Gulbekian, S. L. Bogomolov, B. N. Gikal, A. N. Mezentsev, S. Iliev, V. G. Subbotin, A. M. Sukhov, A. A. Voinov, G. V. Buklanov, K. Subotic, V. I. Zagrebaev, and M. G. Itkis
Joint Institute for Nuclear Research, 141980 Dubna, Russian Federation

J. B. Patin, K. J. Moody, J. F. Wild, M. A. Stoyer, N. J. Stoyer, D. A. Shaughnessy, J. M. Kenneally, and R. W. Lougheed
University of California, Lawrence Livermore National Laboratory, Livermore, California 94551, USA

(Received 1 December 2003; published 17 May 2004)

We have studied the excitation functions of the reactions $^{244}Pu(^{48}Ca,xn)$. Maximum cross sections for the evaporation of 3–5 neutrons in the complete-fusion reaction $^{244}Pu+^{48}Ca$ were measured to be $\sigma_{3n}=2$ pb, $\sigma_{4n}=5$ pb, and $\sigma_{5n}=1$ pb. The decay properties of $3n$-evaporation product $^{289}114$, in the decay chains observed at low ^{48}Ca energy coincide well with those previously observed in the $^{244}Pu+^{48}Ca$ and $^{248}Cm+^{48}Ca$ reactions and assigned to $^{288}114$. Two isotopes of element 114 and their descendant nuclei were identified for the first time at higher bombarding energies: $^{288}114$ (E_α=9.95 MeV, $T_{1/2}$=0.6 s) and $^{287}114$ (E_α=10.04 MeV, $T_{1/2}$=1 s). We also report on the observation of new isotopes of element 116, $^{290,291}116$, produced in the $^{245}Cm+^{48}Ca$ reaction with cross sections of about 1 pb. A discussion of self-consistent interpretations of all observed decay chains originating at Z=118, 116, and 114 is presented.

Oganessian PRC69 (2004): Z=118

B. Synthesis of Z=116 nuclei in the reaction ^{245}Cm+^{48}Ca

This experiment was designed to investigate the radioactive properties of the isotopes of element 116, the α-decay daughters of Z=118 isotopes produced in the reaction ^{249}Cf+^{48}Ca [3].

[3] Yu. Ts. Oganessian *et al.*, JINR Communication D7-2002-287, 2002; Lawrence Livermore National Laboratory Report, UCRL-ID-151619, 2003.

APS: Physics News Update October

Physical Review Focus

Selections from *Physical Review* and *Physical Review Letters* explained for students and researchers in all fields of physics.

APS physics

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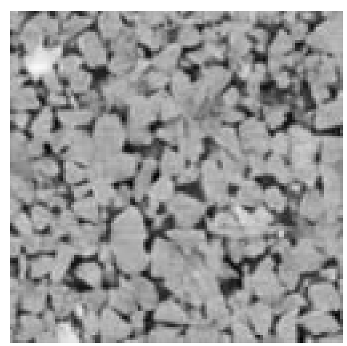
Tracking Nuclei on the Move

25 October 2006

A new technique tracks the motion of water molecules through pores in rocks, which could help in oil prospecting.

PRL (27 October 2006)



Physics News Update

American Institute of Physics news items that describe research from APS journals:

Elements 116 and 118 are Discovered

PRC (October 2006)

Various shapes of superheavy nuclei

- **Old picture: Spherical. Z=114 and N=184**.

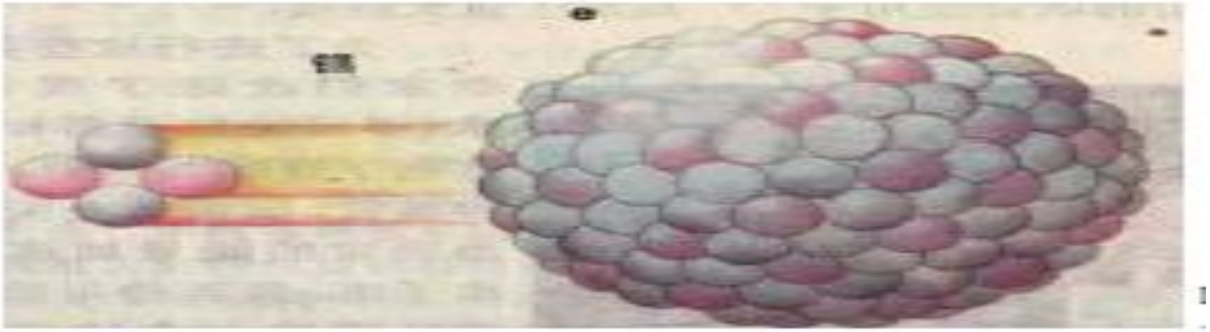
- **Prof. Greiner: Fullerene (Buckyball, ^{60}C). (sixty alpha particles for Z=120)**

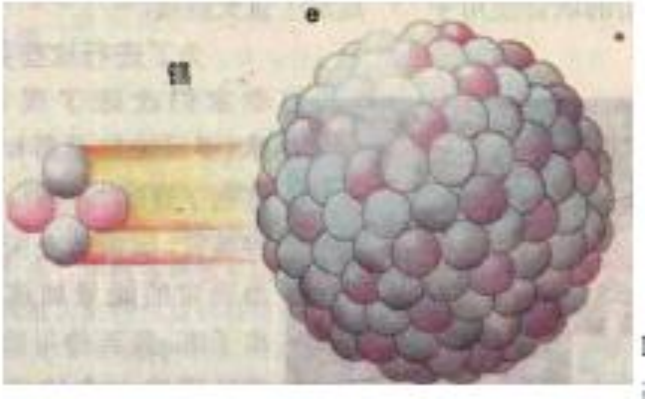
- **Other idea: American football . (Isomers)**

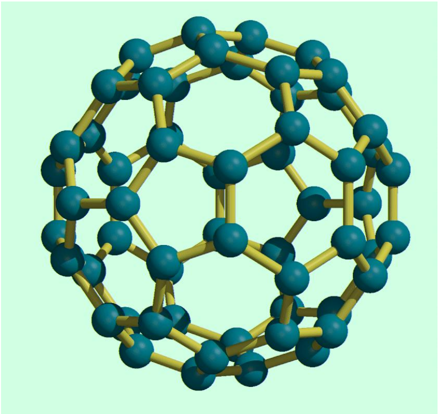
(shape coexistence or superdeformation).

- **Which shape do you prefer ?**

Superheavy nuclei: American football; round ball; Soccer (^{60}C)







新元素 Z=122？ (2008. 04)

Evidence for a long-lived superheavy nucleus with atomic mass number A = 292 and atomic number Z ≅ 122 in natural Th

A. Marinov[1], I. Rodushkin[2], D. Kolb[3], A. Pape[4], Y. Kashiv[1], R. Brandt[5], R.V. Gentry[6] & H.W. Miller[7]

[1]*Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel*

Evidence for the existence of a superheavy nucleus with atomic mass number A=292 and abundance (1-10)x10^{-12} relative to ^{232}Th has been found in a study of natural Th using inductively coupled plasma-sector field mass spectrometry. The measured mass matches the predictions[1,2] for the mass of an isotope with atomic number Z=122 or a nearby element. Its estimated half-life of $t_{1/2} \geq 10^8$ y suggests that a long-lived isomeric state exists in this isotope. The possibility that it might belong to a new class of long-lived high spin super- and hyperdeformed isomeric states is discussed.[3-6]

Possible New Element Could Rewrite Textbooks

Tuesday, April 29, 2008
FOX NEWS

An international team of researchers may, just may, have made a radical breakthrough that could rewrite physics and chemistry textbooks.

They claim to have discovered a naturally occurring element with an atomic number (number of protons) of 122 — 30 notches on the periodic table ahead of uranium, long considered the heaviest naturally occurring element.

For decades, physicists have been making artificial elements in supercolliders, only to see most of their creations disintegrate within a short time.

Most elements above atomic number 100 are inherently unstable and get progressively more usntable as you travel upward. The highest discovered one, ununoctium or atomic number 118, has a half-life of 89 milliseconds.

But according to theory, there exists an "island of stability" further out along the periodic table where certain configurations of protons and neutrons would create superheavy but also superstable elements.

RELATED

STORIES
- Earth Gives Off Mysterious Low

So a team led by Amnon Marinov of the Hebrew University of Jerusalem took a different approach. They figured that if superheavy, superstable elements really are possible, then they ought to already exist in nature.

Synthesis of the 117th element, PRL

Selected for a Viewpoint in *Physics*
PRL **104,** 142502 (2010) PHYSICAL REVIEW LETTERS week ending 9 APRIL 2010

Synthesis of a New Element with Atomic Number $Z = 117$

Yu. Ts. Oganessian,[1,*] F. Sh. Abdullin,[1] P. D. Bailey,[2] D. E. Benker,[2] M. E. Bennett,[3] S. N. Dmitriev,[1] J. G. Ezold,[2] J. H. Hamilton,[4] R. A. Henderson,[5] M. G. Itkis,[1] Yu. V. Lobanov,[1] A. N. Mezentsev,[1] K. J. Moody,[5] S. L. Nelson,[5] A. N. Polyakov,[1] C. E. Porter,[2] A. V. Ramayya,[4] F. D. Riley,[2] J. B. Roberto,[2] M. A. Ryabinin,[6] K. P. Rykaczewski,[2] R. N. Sagaidak,[1] D. A. Shaughnessy,[5] I. V. Shirokovsky,[1] M. A. Stoyer,[5] V. G. Subbotin,[1] R. Sudowe,[3] A. M. Sukhov,[1] Yu. S. Tsyganov,[1] V. K. Utyonkov,[1] A. A. Voinov,[1] G. K. Vostokin,[1] and P. A. Wilk[5]

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(Received 15 March 2010; published 9 April 2010)

The discovery of a new chemical element with atomic number $Z = 117$ is reported. The isotopes $^{293}117$ and $^{294}117$ were produced in fusion reactions between ^{48}Ca and ^{249}Bk. Decay chains involving 11 new nuclei were identified by means of the Dubna gas-filled recoil separator. The measured decay properties show a strong rise of stability for heavier isotopes with $Z \geq 111$, validating the concept of the long sought island of enhanced stability for superheavy nuclei.

PHYSICAL REVIEW C **87**, 024310 (2013)

Nuclear charge radii of heavy and superheavy nuclei from the experimental α-decay energies and half-lives

Dongdong Ni,[1,*] Zhongzhou Ren,[1,2,3,†] Tiekuang Dong,[4] and Yibin Qian[1]
[1]*Department of Physics, Nanjing University, Nanjing 210093, China*
[2]*Center of Theoretical Nuclear Physics, National Laboratory of Heavy-Ion Accelerator, Lanzhou 730000, China*
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(Received 10 December 2012; revised manuscript received 18 January 2013; published 13 February 2013)

The radius of a nucleus is one of the important quantities in nuclear physics. Although there are many researches on ground-state properties of superheavy nuclei, researches on charge radii of superheavy nuclei are rare. In this article, nuclear root-mean-square (rms) charge radii of heavy and superheavy nuclei are extracted from the experimental α-decay data. α-decay calculations are performed within the generalized density-dependent cluster model, where α-decay half-lives are evaluated using quasibound state wave functions. The charge distribution of daughter nuclei is determined in the double-folding model to reproduce the experimental α-decay half-lives. The rms charge radius is then calculated using the resulting charge distribution. In addition, a simple formula is also

First result on charge radii of superheavy nuclei by decay data

The two different methods show good agreement with the experimental data for even-even nuclei, and the deduced results are consistent with other theoretical models. Moreover, nuclear radii of heavy and superheavy nuclei with $Z = 98$–116 are extracted from the α-decay data, for which α decay is a unique tool to probe nuclear sizes at present. This is the first result on nuclear charge radii of superheavy nuclei based on the experimental α-decay data.

PRC 87 (2013) 054323: Nuclear charge radii from decay data of cluster and proton emissions

PHYSICAL REVIEW C **87**, 054323 (2013)

Attempt to probe nuclear charge radii by cluster and proton emissions

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(Received 19 April 2013; published 20 May 2013)

We deduce the rms nuclear charge radii for ground states of light and medium-mass nuclei from experimental data of cluster radioactivity and proton emission in a unified framework. On the basis of the density-dependent cluster model, the calculated decay half-lives are obtained within the modified two-potential approach. The charge distribution of emitted clusters in the cluster decay and that of daughter nuclei in the proton emission are determined to correspondingly reproduce the experimental half-lives within the folding model. The obtained charge distribution is then employed to give the rms charge radius of the studied nuclei. Satisfactory agreement between theory and experiment is achieved for available experimental data, and the present results are found to be consistent with theoretical estimations. This study is expected to be helpful in the future detection of nuclear sizes, especially for these exotic nuclei near the proton dripline.

PRC 89 (2014) 024318: Nuclear charge radii of superheavy odd-mass and odd-odd nuclei from α-decay data

PHYSICAL REVIEW C **89**, 024318 (2014)

Tentative probe into the nuclear charge radii of superheavy odd-mass and odd-odd nuclei

Yibin Qian,[1,2,*] Zhongzhou Ren,[1,2,3,4,†] and Dongdong Ni[1,2]

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(Received 12 December 2013; revised manuscript received 20 January 2014; published 26 February 2014)

The root-mean-square (rms) nuclear charge radii of superheavy odd-A and odd-odd nuclei are tentatively pursued by the deduction of experimental α decay data. The framework of calculating α decay half-lives is constructed via the combination of the improved two-potential approach with the density-dependent cluster model. In this procedure, the charge distribution of daughter nuclei is determined to exactly reproduce the measured α decay half-lives. Next, the rms charge radius of daughter nuclei is obtained by using the corresponding charge distribution. For comparison, the previously proposed formula of our group is employed to estimate the rms charge radii as well. Besides the reasonable agreement between the extracted nuclear charge radii and the available experimental values, the nuclear radii of heaviest odd-A and odd-odd nuclei are extracted from the α decay energies and half-lives. This can be considered as an effective attempt in terms of the nuclear size in the superheavy mass region.

Qian and Ren, PLB 738 (2014) 87-91:
Half-lives of α-decay from superheavy elements

Physics Letters B 738 (2014) 87–91

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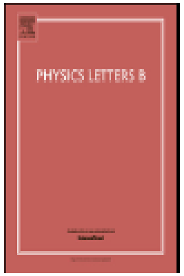

Half-lives of α decay from natural nuclides and from superheavy elements

CrossMark

Yibin Qian [a,b,*], Zhongzhou Ren [a,b,c,d,*]

[a] Key Laboratory of Modern Acoustics and Department of Physics, Nanjing University, Nanjing 210093, China
[b] Joint Center of Nuclear Science and Technology, Nanjing University, Nanjing 210093, China
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[d] Center of Theoretical Nuclear Physics, National Laboratory of Heavy-Ion Accelerator, Lanzhou 730000, China

轻—中重核：α预形成因子，中重核区计算

Physics Letters B 777 (2018) 298–302

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PHYSICS LETTERS B

New insight into α clustering of heavy nuclei via their α decay

Check for updates

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[b] *School of Physics, Nanjing University, Nanjing 210093, China*
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Physics Letters B 786 (2018) 5–10

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PHYSICS LETTERS B

Cluster-daughter overlap as a new probe of alpha-cluster formation in medium-mass and heavy even–even nuclei

Check for updates

Dong Bai [a], Zhongzhou Ren [b,*]

[a] *School of Physics, Nanjing University, Nanjing, 210093, China*
[b] *School of Physics Science and Engineering, Tongji University, Shanghai, 200092, China*

PRL 122, 192503 (2019) 产生一个新核素^{220}Np，
研究了N = 126幻数对应的闭壳效应。PRL编辑建议文章。
同济大学任中洲教授 (作者之一)

PHYSICAL REVIEW LETTERS **122,** 192503 (2019)

Editors' Suggestion

New Isotope ^{220}Np: Probing the Robustness of the $N = 126$ Shell Closure in Neptunium

Z. Y. Zhang (张志远),[1,2] Z. G. Gan (甘再国),[1,2,*] H. B. Yang (杨华彬),[1] L. Ma (马龙),[1] M. H. Huang (黄明辉),[1,2] C. L. Yang (杨春莉),[1,2] M. M. Zhang (张明明),[1,2] Y. L. Tian (田玉林),[1,2] Y. S. Wang (王永生),[1,2,3] M. D. Sun (孙明道),[1,2,3,†] H. Y. Lu (卢洪洋),[1,2] W. Q. Zhang (张文强),[1,2] H. B. Zhou (周厚兵),[4] X. Wang (王翔),[5] C. G. Wu (武晨光),[5] L. M. Duan (段利敏),[1,2] W. X. Huang (黄文学),[1,2] Z. Liu (刘忠),[1,2] Z. Z. Ren (任中洲),[6] S. G. Zhou (周善贵),[7,8] X. H. Zhou (周小红),[1,2] H. S. Xu (徐瑚珊),[1,2] Yu. S. Tsyganov,[9] A. A. Voinov,[9] and A. N. Polyakov[9]

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(Received 9 January 2019; revised manuscript received 10 April 2019; published 16 May 2019)

PRL 125, 032502 (2020) 在兰州产生另一个新核素 ^{222}Np，深入研究N = 126闭壳附近阿尔法衰变。同济大学任中洲教授 (作者之一)

PHYSICAL REVIEW LETTERS 125, 032502 (2020)

Short-Lived α-Emitting Isotope ^{222}Np and the Stability of the $N = 126$ Magic Shell

L. Ma (马龙),[1] Z. Y. Zhang (张志远),[1,2,*] Z. G. Gan (甘再国),[1,2] X. H. Zhou (周小红),[1,2,†] H. B. Yang (杨华彬),[1] M. H. Huang (黄明辉),[1] C. L. Yang (杨春莉),[1] M. M. Zhang (张明明),[1,2] Y. L. Tian (田玉林),[1] Y. S. Wang (王永生),[1,2,3] H. B. Zhou (周厚兵),[4] X. T. He (贺晓涛),[5] Y. C. Mao (毛英臣),[6] W. Hua (滑伟),[7] L. M. Duan (段利敏),[1,2] W. X. Huang (黄文学),[1,2] Z. Liu (刘忠),[1,2] X. X. Xu (徐新星),[1,2] Z. Z. Ren (任中洲),[8] S. G. Zhou (周善贵),[9,10,11,12] and H. S. Xu (徐瑚珊)[1,2]

任中洲

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(Received 8 May 2020; revised 22 June 2020; accepted 26 June 2020; published 13 July 2020)

2020年一篇研究工作

理论----实验----理论：互动, ^{220}Np, ^{219}Np

PHYSICAL REVIEW C **101**, 054310 (2020)

Theoretical studies on α-decay half-lives of $N = 125$, 126, and 127 isotones

Zhen Wang,[1] Zhongzhou Ren,[1,2,*] and Dong Bai[1]
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(Received 14 January 2020; revised manuscript received 30 March 2020; accepted 27 April 2020; published 15 May 2020)

The α decays of exotic $N = 125$, 126, and 127 isotones, including two new isotopes ^{219}Np [Phys. Lett. B **777**, 212 (2018)] and ^{220}Np [Phys. Rev. Lett. **122**, 192503 (2019)], are studied by using the improved Buck-Merchant-Perez cluster model with the charge-dependent α-preformation factors. The experimental half-lives of α decays varying from 2.50×10^{-5} to 6.00×10^{26} s are reproduced within a factor of ≈ 2. Noticeably, the theoretical α-decay half-lives of the new isotopes ^{219,220}Np are also in good agreement with the experimental data. Furthermore, the α-decay half-lives of some undiscovered $N = 125$, 126 and 127 isotones are predicted, which could be useful for future experimental studies on the robustness of the magic number $N = 126$.

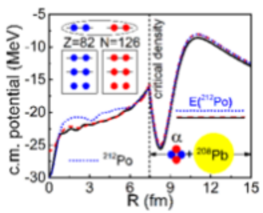
PHYSICAL REVIEW C
covering nuclear physics

Editors' Suggestion

α decay to a doubly magic core in the quartetting wave function approach

Shuo Yang, Chang Xu, Gerd Röpke, Peter Schuck, Zhongzhou Ren, Yasuro Funaki, Hisashi Horiuchi, Akihiro Tohsaki, Taiichi Yamada, and Bo Zhou

Phys. Rev. C **101**, 024316 (2020) – Published 28 February 2020



This microscopic calculation for the α decay of heavy nuclei provides a solution to what has long been an outstanding problem. In the authors' model, the α particle exists only below about one-fifth of saturation density, corresponding to a large radius, inside of which the α particle transitions into an unbound four-nucleon shell-model state. The model reproduces the half-life of ^{212}Po (a classic test case) as well as some neighboring nuclei, and calculations are also made for ^{104}Te.

编辑推荐并评价为“该微观衰变模型为这一长期难点问题提供了解决办法”

S. Yang, C. Xu, G. Roepke, P. Schuck, Z. Ren et al., PRC101, 024316 (2020)

^{214}U：ZY Zhang et al., PRL 126 (2021) 152502
PRL编辑推荐+featured in Physics(APS)

PHYSICAL REVIEW LETTERS **126**, 152502 (2021)

Editors' Suggestion Featured in Physics

New α-Emitting Isotope ^{214}U and Abnormal Enhancement of α-Particle Clustering in Lightest Uranium Isotopes

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ZY Zhang et al., PRL 126 (2021) 152502 编辑推荐+ Featured in Physics

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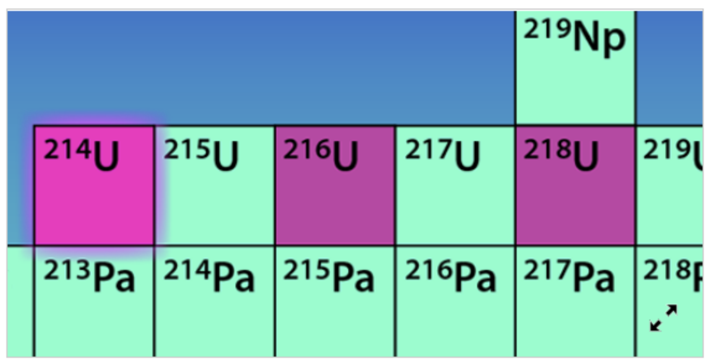
SYNOPSIS

A Lightweight Among Heavyweights

April 14, 2021 • *Physics* 14, s43

Researchers have observed the lightest uranium isotope to date, offering insight into models of nuclear structure.



APS/Carin Cain

Discovering new isotopes is like the stamp collecting of physics, but the consequences of adding to the set are much further reaching. A team of researchers using the Heavy Ion Research Facility in Lanzhou, China, has now expanded

TEXAS A&M UNIVERSITY

JINR FLNR Dubna

Super Heavy Nuclei International Symposium

Texas A&M University, College Station Texas, USA

March 31 - April 02, 2015

In the past forty years, twelve new elements have been synthesized and more than a hundred new nuclides have been produced. We have advanced by forty atomic mass units in a search for the limits of nuclear matter, but we have not reached these limits yet. Nevertheless, we have obtained new knowledge on the properties of the heaviest nuclei and in many cases we have confirmed the theoretical predictions.

New powerful accelerators, neutron-rich actinide targets and radioactive isotope beams together with high-efficiency experimental facilities will give us a unique opportunity to make significant progress in exploring the nature and properties of the heavy and super-heavy nuclei at the borders of nuclear masses.

Topics

- At the Border of the Island of the Super-Heavy Nuclei
- Decay Properties and Nuclear Structure of the Heaviest Nuclei
- Reactions of Synthesis of New Elements and Isotopes
- Super-Heavy Atoms. Chemistry of the Super-Heavy Elements

2016年 Z=113、115、117、118 已被确认。

2021 诺贝尔物理奖 花落谁家？

美媒：元素周期表将增加四种元素 2016年初公布

来源:参考消息网 2016-01-02 15:51 http://www.mnw.cn/ 海峡都市报电子版

美国《科学新闻》双周刊网站12月31日发表了题为《四种元素在元素周期表上获得永久席位》的报道，编译如下：

2015年12月30日，国际纯粹与应用化学联合会（IUPAC）宣布俄罗斯和美国的研究团队已获得充分的证据，证明其发现了115、117和118号元素。此外，该联合会已认可日本理化学研究所的科研人员发现了113号元素。两个研究团队通过让质量较轻的核子相互撞击，并跟踪其后产生的放射性超重元素的衰变情况，合成了上述四种元素。

俄罗斯杜布纳联合原子核研究所与美国加利福尼亚劳伦斯利弗莫尔国家实验室的研究人员，已被确认发现了115、117和118号元素。在2004年和2007年展开实验后，他们还声称发现了113号元素。负责领导利弗莫尔实验核物理和放射能化学研究小组的道恩·肖内西说，赢得IUPAC对其发现其他三种元素的认可已令人为之一振。她说：“就个人而言，我对IUPAC的决定感到非常高兴。”

Name: Z=113,115,117,118

- Z=113: Nihonium, Nh.
- Z=115: Moscovium, Mc.
- Z=117: Tennessine, Ts.
- Z=118: Oganesson; Og.

中国好运：2015 诺贝尔生理和医学奖
屠呦呦 中国本土科学家

The Nobel Prize in Physiology or Medicine 2015
William C. Campbell, Satoshi Ōmura, Youyou Tu

Share this: 636

Youyou Tu - Facts

Photo: A. Mahmoud

Youyou Tu

Born: 30 December 1930, Zhejiang Ningpo, China

Affiliation at the time of the award: China Academy of Traditional Chinese Medicine, Beijing, China

Prize motivation: "for her discoveries concerning a novel therapy against Malaria"

Prize share: 1/2

A Novel Therapy against Malaria

A number of serious infectious diseases are caused by parasites spread by insects. Malaria is caused by a single-cell parasite that causes severe fever.

5. Summary

- **Review on present researches of new elements and new nuclei**
- **Best efforts for production new elements (New accelerators in China)**

- **Theory: New, New, New !!!**
- **Experiments: New, New, New !!!**

中国核物理学家之梦：新元素（新装置）．Chinium：金龙

很高兴再次来到美丽湖州进行学术交流，

谢谢各位老师的邀请，漂亮的湖师校园！

谢 谢！

THANKS!

Thanks

- **Thanks for your attention of this talk**
- **祝愿各位老师和同学健康，快乐！**

Rudolf Ludwig Mössbauer

"for his researches concerning the resonance absorption of gamma radiation and his discovery in this connection of the effect which bears his name"

The Nobel Prize in Physics 1960

Donald Arthur Glaser

"for the invention of the bubble chamber"

The Nobel Prize in Physics 1959

Emilio Gino Segrè and Owen Chamberlain

"for their discovery of the antiproton"

The Nobel Prize in Physics 1958

Pavel Alekseyevich Cherenkov, Il´ja Mikhailovich Frank and Igor Yevgenyevich Tamm

"for the discovery and the interpretation of the Cherenkov effect"

The Nobel Prize in Physics 1957

Chen Ning Yang and Tsung-Dao (T.D.) Lee

"for their penetrating investigation of the so-called parity laws which has led to important discoveries regarding the elementary particles"

周期表 (1869): 门捷列夫未获 Nobel Prize . Why?

ОПЫТЬ СНСТЕМЫ ЗЛЕМЕНТОВЬ

ОСНОВАННОИ НА ИХЬ АТОМНОМЬ ВЪСЪ И ХИМНЧЕСКОМЬ СХОДСТОЬ

			Ti = 50	Zr = 90	? = 180
			V = 51	Nb = 94	Ta = 182
			Cr = 52	Mo = 96	W = 186
			Mn = 55	Rh = 104. 4	Pt = 197. 4
			Fe = 56	Rn = 104. 4	Ir = 198
			Ni = Co = 59	Pl = 106. 6	Os = 199
H = 1			Cu = 63. 4	Ag = 108	Hg = 200
	Be = 9. 4		Mg = 24	Zn = 65. 2	Cd = 112
	B = 11	Al = 27. 4	? = 68	Ur = 116	Au = 197?
	C = 12	Si = 28	? = 70	Sn = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
	O = 16	S = 32	Se = 79. 4	Ta = 128?	
	F = 19	Cl = 35. 5	Br = 80	J = 127	
Li = 7	Na = 23	K = 39	Rb = 85. 4	Cs = 133	Ti = 204
		Ca = 40	Sr = 87. 6	Ba = 137	Pb = 207
		? = 45	Ce = 92		
		?Er = 56	La = 94		
		?Yt = 60	Di = 95		
		?In = 75. 6	Th = 118?		

Д. МенАелеевъ

门捷列夫元素周期表初稿(1869 年)

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Synthesis of nuclei of the superheavy element 114 in reactions induced by ^{48}Ca

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The stability of heavy nuclides, which tend to decay by α-emission and spontaneous fission, is determined by the structural properties of nuclear matter. Nuclear binding energies and lifetimes increase markedly in the vicinity of closed shells of neutrons or protons (nucleons), corresponding to 'magic' numbers of nucleons; these give rise to the most stable (spherical) nuclear shapes in the ground state. For example, with a proton number of $Z = 82$ and a neutron number of $N = 126$, the nucleus ^{208}Pb is 'doubly-magic' and also exceptionally stable. The next closed neutron shell is expected at $N = 184$, leading to the prediction of an 'island of stability' of superheavy nuclei, for a broad range of isotopes with $Z = 104$ to 120 (refs 1, 2). The heaviest known nuclei have lifetimes of less than a millisecond, but nuclei near the top of the island of stability are predicted to exist for many years. (In contrast, nuclear matter consisting of about 300 nucleons with no shell structure would undergo fission within about 10^{-20} seconds.) Calculations[3–5] indicate that nuclei with $N > 168$ should already benefit from the stabilizing influence of the closed shell at $N = 184$. Here we report the synthesis of an isotope containing 114 protons and 173 neutrons, through fusion of intense beams of ^{48}Ca ions with ^{242}Pu targets. The isotope decays by α-emission with a half-life of about five seconds, providing experimental confirmation of the island of stability.

Neutron-rich nuclei with $N > 168$ can be synthesized, as we have shown earlier[6], in fusion reactions using the heaviest isotopes of uranium, plutonium and curium as targets and a ^{48}Ca ion beam. As a result of the significant mass defect of the doubly magic ^{48}Ca nucleus (magic numbers $N = 28$ and $Z = 20$), the excitation energy (E_x) of the compound nucleus at the Coulomb barrier only amounts to about 30 MeV. This corresponds to an energy $E_{lab} = 230$–235 MeV of the ^{48}Ca bombarding projectiles. The de-excitation of this nucleus should proceed mainly by the emission of three neutrons and γ-rays[7,8]. Calculations predict that the probability for the excited compound nucleus to reach the final state (evaporation residue, EVR) after the evaporation of 2 or 4 neutrons is one order of magnitude less at the bombarding ion energy near the Coulomb barrier. This circumstance should increase the survival probability of the EVRs as compared with the case of hot fusion reactions ($E_x \approx 50$ MeV), which were used for the synthesis of heavy isotopes of elements with atomic numbers $Z = 106$, 108 and 110 (refs 9–11). On the other hand, the high asymmetry of the interacting nuclei in the entrance channel ($A_p/A_T = 0.2$, $Z_p/Z_T = 1{,}880$, where A_p, A_T and Z_p, Z_T are mass and atomic numbers of the projectile and target nuclei respectively) should decrease possible dynamical limitations[12] on the fusion of massive nuclei as compared with more symmetrical cold fusion reactions.

In spite of these obvious advantages, previous attempts to synthesize new elements in ^{48}Ca-induced reactions gave only the upper limits of the production cross-sections of superheavy elements[13–15]. As is apparent now, this could be explained by the low experiment sensitivity, as the intensity of the ^{48}Ca beam was not high enough.

The first positive result was obtained in spring 1998 in the $^{48}Ca + {}^{238}U$ reaction with a total beam dose of 3.5×10^{18} Ca ions. Two spontaneous fission events were observed, which were assigned to the decay of a new isotope of element 112 produced in the reaction $^{238}U(^{48}Ca,3n)^{283}112$ with a cross-section of $\sigma_{3n} = 5^{+6}_{-3}$ picobarn (pb, 10^{-36} cm^2)[16]. The cross-section value of 1 pb corresponds to the observation of one wanted event within 4 days, providing that the beam intensity is 4×10^{12} particles per second, the number of target nuclei able to take part in the fusion reaction is 5×10^{17} and the experiment efficiency is 100%. The half-life of the new nuclide against spontaneous fission (T_{SF}), determined on the basis of the two events, was ~1.5 min. This is about 3×10^5 times longer than the α-decay half-life (T_α) of the known lighter isotope of element 112, synthesized in the reaction $^{208}Pb(^{70}Zn,1n)^{277}112$ by Hofmann *et al.*[17] in 1996 (Fig. 1a).

The next experiment, performed at the end of 1998, was aimed at the synthesis of nuclei with $Z = 114$ in the reaction $^{48}Ca + {}^{244}Pu$. In a 34-day irradiation with a beam dose of Ca ions of 5.3×10^{18}, a decay chain—consisting of three sequential α-decays and spontaneous fission, taking about 34 min in all—was observed after the implantation of a heavy atom in the detector[18]. This decay chain may be considered as a good candidate for originating from

Relativistic mean-field model

- **Protons and neutrons interact by exchanges of mesons (strong interactions)**
- **There is the electromagnetic interactions among protons by exchange of photons**

- **Atomic nucleus is a many-body system**
- **Solve the coupled Dirac equations**
- **and the Klein-Gordon equations**

Density-Dependent Cluster Model

- 建立了球形和形变核双折叠势程序
- 推导了球形，形变核**alpha**衰变寿命公式
- 对已知**alpha**衰变寿命进行了大规模计算
- 对结团放射性进行了系统研究

PRC 87 (2013) 054323: Nuclear charge radii from decay data of cluster and proton emissions

PHYSICAL REVIEW C **87**, 054323 (2013)

Attempt to probe nuclear charge radii by cluster and proton emissions

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(Received 19 April 2013; published 20 May 2013)

We deduce the rms nuclear charge radii for ground states of light and medium-mass nuclei from experimental data of cluster radioactivity and proton emission in a unified framework. On the basis of the density-dependent cluster model, the calculated decay half-lives are obtained within the modified two-potential approach. The charge distribution of emitted clusters in the cluster decay and that of daughter nuclei in the proton emission are determined to correspondingly reproduce the experimental half-lives within the folding model. The obtained charge distribution is then employed to give the rms charge radius of the studied nuclei. Satisfactory agreement between theory and experiment is achieved for available experimental data, and the present results are found to be consistent with theoretical estimations. This study is expected to be helpful in the future detection of nuclear sizes, especially for these exotic nuclei near the proton dripline.

PRC 89 (2014) 024318: Nuclear charge radii of superheavy odd-mass and odd-odd nuclei from α-decay data

PHYSICAL REVIEW C **89**, 024318 (2014)

Tentative probe into the nuclear charge radii of superheavy odd-mass and odd-odd nuclei

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The root-mean-square (rms) nuclear charge radii of superheavy odd-A and odd-odd nuclei are tentatively pursued by the deduction of experimental α decay data. The framework of calculating α decay half-lives is constructed via the combination of the improved two-potential approach with the density-dependent cluster model. In this procedure, the charge distribution of daughter nuclei is determined to exactly reproduce the measured α decay half-lives. Next, the rms charge radius of daughter nuclei is obtained by using the corresponding charge distribution. For comparison, the previously proposed formula of our group is employed to estimate the rms charge radii as well. Besides the reasonable agreement between the extracted nuclear charge radii and the available experimental values, the nuclear radii of heaviest odd-A and odd-odd nuclei are extracted from the α decay energies and half-lives. This can be considered as an effective attempt in terms of the nuclear size in the superheavy mass region.