

Pushing the limit of the periodic table with superheavy elements

March 19 2024

		Group																			
Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Orbital		
1	1 H																		2 He	1s	
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	2s2p		
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	3s3p		
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	4s3d4p		
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	5s4d5p		
6	55 Cs	56 Ba	57-71	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	6s5d6p		
7	87 Fr	88 Ra	89-103	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	7s6d7p		
8	119	120	121-	156	157	158	159	160	161	162	163	164	139	140	169	170	171	172	8s7d8p		
9	165	166											167	168					9s9p		
6	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					4f	
7	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					5f	
8	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155					6f	
8	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	5g		

Credit: *Physics Reports* (2023). DOI: 10.1016/j.physrep.2023.09.004

Scientists from Massey University in New Zealand, the University of Mainz in Germany, Sorbonne University in France, and the Facility for Rare Isotope Beams (FRIB) discuss the limit of the periodic table and revising the concept of the "island of stability" with recent advances in superheavy element research. Their work first appeared in *Nature Reviews Physics*.

In addition to the *Nature Reviews Physics* [feature](#), *Physics Reports* has published a [review](#) on the atomic electronic structure theory for superheavy elements.

What is the heaviest bound nucleus and the heaviest bound atom and what are their properties? The nuclei of chemical elements with more than 103 protons are labeled as "superheavy." They are part of a vast unknown territory of these nuclei that scientists are trying to uncover. Exploring this uncharted territory provides prospects for discoveries that connect the broad areas of science.

New experimental facilities are being built to help scientists to uncover properties of atoms and their nuclei in a regime of very large numbers of electrons, protons, and neutrons. The facilities will create new elements and nuclides at the limits of atomic number and mass. The production rates of superheavy nuclei are exceedingly low.

The physical and chemical data obtained from these experiments has indicated deviations from lighter elements and isotopes. This allows scientists to question how much further the borders of the Periodic Table of the Elements and the Chart of the Nuclides can be expanded. Assessing the existence of the "peninsula of extended stability," where superheavy nuclei could have lifetimes beyond the very short lived one discovered up to now, is also a scientific goal.

In addition, the progress of atomic structure theory focuses on

[superheavy elements](#) and their predicted electronic ground state configurations, which are important for an element's placement in the [periodic table](#).

"Due to the presence of huge electrostatic forces, electrons in superheavy atoms move with velocities close to [light speed](#)," said one of the authors of the paper, Witek Nazarewicz, John A. Hannah Distinguished Professor of Physics and chief scientist at FRIB. "Also, very strong Coulomb forces in superheavy nuclei give rise to new effects. This is a new ball game for atomic and nuclear theory."

At FRIB, scientists will study ways to reach superheavy nuclei located more closely toward the region of enhanced stability. Many superheavy nuclei cannot be measured currently, so information about them must come from theoretical extrapolations. Nuclear theorists at FRIB carry out predictions for superheavy [nuclei](#) using advanced models aided by [high-performance computing](#) and machine learning.

Studying the Periodic Table of Elements and the nuclear landscape in the superheavy region will generate new ideas and methods that will impact nuclear and atomic [physics](#), astrophysics, and chemistry.

More information: O.R. Smits et al, Pushing the limits of the periodic table — A review on atomic relativistic electronic structure theory and calculations for the superheavy elements, *Physics Reports* (2023). [DOI: 10.1016/j.physrep.2023.09.004](https://doi.org/10.1016/j.physrep.2023.09.004)

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