

A New Approach to Finding Magic Numbers for Heavy and Superheavy Elements

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For at least sixty years, scientists have known that certain numbers of protons or neutrons in nuclei formed closed shells of some kind, producing additional stability to nuclei that possess these properties. The most stable nuclei, or nuclei exhibiting enhanced stability, are called doubly magic. Only recently, Lucas has explained that the magic numbers are really composites of several sub shells filling, rather than being single shells. In addition, his theory leads to a conclusion that protons and neutrons fill sub shells in a different way. This is because the protons are charged particles, and by Coulomb repulsion they try to get as far away from each other as possible, hence tending to occupy the outer regions of nuclei. Neutrons, being uncharged but possibly polarizable, tend to occupy both outer and inner shells and to possibly increase the number in an outer shell when the nuclei are heavy in a similar way to electrons filling in inner shells in the Lanthanide and Actinide series. Using these ideas, and following a simple modification of Lucas' geometrical packing scheme, individual candidates for new magic proton numbers and new magic neutron numbers have been identified. Amazingly, these new magic numbers correspond to the experimentally identified superheavy element distribution to a very large extent, and even correspond to magic numbers suggested using very sophisticated theoretical physics methods and computations. As an added bonus, the newly suggested magic numbers correspond to the long lived Thorium and Uranium isotopes, and to the Fermium isotopes, which may help explain the shape of the Peninsula of Heavy isotopes. They also suggest going back to reassess somewhat lighter isotopes to see if some magic effects have been missed.

1. Magic Numbers

From Wikipedia [1], "In nuclear physics, a magic number is a number of nucleons (either protons or neutrons) such that they are arranged into complete shells within the atomic nucleus. The seven most widely recognized magic numbers as of 2007 are:

2, 8, 20, 28, 50, 82, and 126 (for neutrons)

Atomic nuclei consisting of such a magic number of nucleons have a higher average binding energy per nucleon than one would expect, and are hence more stable against nuclear decay."

"Nuclei which have both neutron number and proton atomic number equal to one of the magic numbers are called "doubly magic", and are especially stable against decay. Examples of stable doubly magic isotopes include Helium-4 (2, 2), Oxygen-16 (8, 8), Calcium-40 (20, 20), Calcium-48 (20, 28), Nickel-48 (28, 20) and Lead-208 (82, 126). Tin-100 (50, 50) and Tin-132 (50, 82) are doubly-magic isotopes of tin that are unstable; however they represent endpoints beyond which stability drops off rapidly. It is no accident that Helium-4 (^4He) is among the most abundant (and stable) nuclei in the universe, and that Lead-208 (^{208}Pb) is the heaviest stable nuclide."

"Both Calcium-48 (^{48}Ca) and Nickel-48 (^{48}Ni) are doubly magic because Calcium-48 has 20 protons and 28 neutrons while Nickel-48 has 28 protons and 20 neutrons. Calcium-48 is very neutron-rich for such a light element, but is made stable by being doubly magic. Similarly, Nickel-48, discovered in 1999, is the most proton-rich isotope known beyond Helium-3." Magic effects in binding energy per nucleon are most visible for $A < 30$ in terms of magnitude changes.

2. Superheavy Elements

From Wikipedia [1] (with minor modifications), "The unusual extra stability of isotopes having magic numbers implies that extremely heavy transuranic elements can be produced that are not subject to the short half life radioactive decay normally associated with high atomic numbers (as of 2007, the longest-lived, known isotope among all of the superheavy elements between $Z = 110$ and 120 lasts only 12 minutes, and the next longest lasts 22 seconds). Superheavy isotopes with magic numbers of nucleons are said to exist in an "island" of stability. Unlike the magic numbers 2 to 126, which are realized in spherical nuclei, theoretical calculations predict that superheavy nuclei can be deformed. Before this possibility was considered, higher magic numbers, such as 184, were predicted based on simple calculations that assumed spherical shapes." The superheavy nuclei decay primarily by alpha decay, with spontaneous fission as an additional decay mode. Areas of stability for deformed nuclei have been predicted around $N = 152, 164$ and 172 [2].

From Gupta [3], "The superheavy elements are traditionally considered to be those that lie above element 103 (Lawrencium, Lr), the last of the actinides. Starting with Rutherfordium (Rf), element 104, these elements are sometimes referred to as the super-transactinides. Collectively, they represent the very top end of the Periodic Table of Elements and a study of their properties is intrinsically linked to an understanding of the physics and chemistry at the limit of stability in mass and charge. The limitation on the number of chemical elements possible remains a long standing question."

“Due to the rapid increase of the repulsive Coulomb forces between the protons, the number of chemical elements is limited by fission. This macroscopic behavior is governed by shell effects, without which the nuclear chart may end near Element 106 (Seaborgium, Sg). There is evidence to suggest that nuclei can survive beyond the macroscopic limit, far into the transuranium region, where the necessary balance between the nuclear force and the Coulomb force is achieved only through shell stabilization. Superheavy elements are hypothesized to exist near the next (predicted) double shell closure above Lead where they may have surprisingly long half-lives, maybe even on the order of millions of years. This postulate has fuelled vigorous research in the field, thereby earning it the reputation of being a search for the next “magic” shell, a Holy Grail of contemporary physics. On the way to this region of extra stability, deformed regions exhibiting stronger binding to varying degree are also suggested.” In fact, there is no experimental data as yet to support the hypothesis that new superheavy doubly magic nuclei will be very much more stable than their neighbors. Magic simply reduces the Q value available for decay, and correspondingly increases the half life.

“Over the past decades, different theories have been put forward in an attempt to uncover the physics of this elusive mass region. Microscopic-Macroscopic (MM) theories traditionally involve a number of parameters and assume prior knowledge of densities and single particle potentials around the mass region of interest. They predict the next “magic” shell at $Z = 114$ and $N = 184$.”

“Both non-relativistic (e.g. Skyrme-Hartree, Fock-Bogoliubov) theory and relativistic microscopic mean field models (RMF) predict probable closures at $Z = 114$ and 120 . The important spin-orbit term is incorporated manually in the non-relativistic theories whereas it emerges naturally within the relativistic formalism. RMF theory utilizes a smaller number of parameters which are obtained through a chi-square fit to the ground state properties of doubly magic and a few open shell spherical nuclei. Taking into account pairing effects, relativistic theory predicts additional shell closures around $Z \sim 108 - 110$; $N \sim 162$ and possibly $N \sim 172$, apart from the ones at $N = 184$ and $Z = 114$. Interestingly, it is seen that predictions of new “magic” numbers depend on the combination of both N and Z .” Indeed, just looking at the plot of the known heavy and superheavy nuclei given in Figure 1, the N/Z ratio for the most stable isotopes needs to be somewhere in the vicinity of 1.54, which only allows certain combinations of magic numbers to come into play.

“With the high density of states expected around the Fermi surface of these extremely heavy nuclei, theories provide a sensitive probe of the physics of the region. Equally importantly, experimentally derived nuclear structure is a requirement for comparison with theory. Since the known shell-stabilized trans-Rutherfordium nuclides exhibit alpha emission as the preferred mode of decay, the experimental quantities available for comparison are alpha decay Q -values and their associated half-lives. A cursory examination of the systematics of the region reveals evidence of greater stability around $N \sim 162$ (e.g. through the decay of the nuclide 277112 measured at Gesellschaft für Schwerionenforschung (GSI), Darmstadt, Germany and in the region around $N \sim 172$ (e.g. through the decay of the 287,288115

nuclides measured at the Flerov Laboratory of Nuclear Reactions (FLNR) at the Joint Institute of Nuclear Research (JINR), Dubna, Russia). Whereas $N = 184$ is yet to be reached, the emerging experimental support is encouraging. Currently, elements up to $Z = 118$ have been artificially synthesized and efforts are on to create $Z = 120$ in the laboratory. Most recently, alpha decay chains assigned to the parents 293,294117 have been reported from Dubna. The most neutron rich element synthesized is still about 7 neutrons away from the “magic” $N = 184$.”

3. Electrodynamical Model of the Nucleus [4]

Nuclear engineers are well aware of the importance of the closed nuclear shell “magic numbers” to nuclear engineering. Magic numbers are responsible for double-hump fission curves, the existence of delayed neutrons, and for xenon poisoning and xenon-induced power oscillations in reactors. Engineers are also aware of the shape of the binding energy per nucleon function, and the fact that fusion is energetically possible for low- A nuclides while fission and alpha decay are energetically possible for high- A nuclides. All of this information came from experimental data. The magic numbers were inferred by noting discontinuities in nuclear systematic studies [5]. The binding energy data were qualitatively fit by the semi-empirical binding energy equation, which was an attempt to combine the liquid drop model and the quantized nuclear shell model. For more than 40 years, no theory was put forward that could quantitatively explain why all of these ideas worked.

Based upon early experimental and theoretical work done by Compton [6-8] and his student Bostick [9], a new qualitative explanation for these phenomena has been obtained. Protons and neutrons are each represented by small charged ring magnets, as suggested by X-ray scattering experiments on electrons [10], and these nucleons are then arranged as symmetrically as possible in three dimensional space so that the electrodynamic forces between them attain static balance. Geometrical packing follows some electrodynamic constraints, so the pattern is not completely arbitrary. The neutron is known to have an internal charge distribution, so it can polarize and orient its positive and negative ends to a position of torque balance.

With this model, Lucas [11] predicts all the magic number shell closings for neutrons and protons and explains why they have the values we know. Using a similar model for atoms, he also predicts the periodic table [12] and shows why nuclear shells are different from atomic shells. For Pb-208, the protons occupy the outermost two rings of 32 and 50, giving the magic number of 82, while the neutrons occupy five different rings of 8, 18, 18, 32, and 50 that add up to 126. The protons get as far away from each other as possible, which is why they occupy the outer shells. Between these two proton shells lies a neutron shell, where the neutrons are polarized sideways. That shell acts like a force decoupler and gives the nucleus its liquid drop properties corresponding to the vibration induced liquid drop model of fission. The rest of the neutrons polarize away from the protons, and the innermost shell is left empty as the positive ends of the neutrons also get as far away from each other as possible. It is the rearrangement and emptying of inner shells when outer shells can be completed that accounts for the difference between

nuclear magic numbers and the atomic magic numbers that correspond to the noble gases.

Lucas uses an 8 cycle shell model each for protons and

neutrons. His original assignments for the known doubly magic nuclides are shown in Table 1. This is a small subset of his complete table.

	A	Z	N	N ₁	P ₁	N ₂	P ₂	N ₃	P ₃	N ₄	P ₄	N ₅	P ₅	N ₆	P ₆	N ₇	P ₇	N ₈	P ₈
He	4	2	2	2	2														
O	16	8	8			8	8												
Ca	40	20	20			6	6	14	14										
Ca	48	20	28	2		8	6	18	14										
Ni	48	28	20	(not given)															
Sn	100	50	50	(not given)															
Sn	132	50	82			6		8		18						50	50		
Pb	208	82	126			8				18		18		32	32			50	50

Table 1. Original Lucas' "Rule" Assignments for Doubly Magic Isotopes

Several comments can be made. The basic Lucas filling structure has eight cycles, but many of the cycles of the heavier nuclei are empty. The basic structure from the inside to the outside is the pattern: 2, 8, 18, 18, 32, and 50. The purpose of the extra shells is not obvious, since 6 cycles could do the job for all of the stable isotopes, especially if the outer shells can at some point continue to fill to the next number like the inner electron shells fill in for the Lanthanide and Actinide series (i.e., if the

inner 18 shell fills to 32 and the inner 32 shell fills to 50 at some point). If the table is narrowed, then the cycles would be as shown in Table 2, with a tentative assignment for Ni-48 and Tin-100 using the logic given above that the protons tend to stay to the outside while neutrons fill in towards the center. That is why Calcium-40 in the Lucas model uses shells of 14 and 6 protons instead of 18 and 2 protons to get to the proton magic number of 20.

	A	Z	N	N ₁	P ₁	N ₂	P ₂	N ₃	P ₃	N ₄	P ₄	N ₅	P ₅	N ₆	P ₆
He	4	2	2	2	2										
O	16	8	8			8	8								
Ca	40	20	20			6	6	14	14						
Ca	48	20	28	2		8	6	18	14						
Ni	48	28	20		2	6	8	14	18						
Sn	100	50	50									18	18	32	32
Sn	132	50	82			6		8		18		18	18	32	32
Pb	208	82	126			8		18		18		32	32	50	50

Table 2. Modified Lucas' "Rule" Assignments for Doubly Magic Isotopes

4. Extension to Possible Superheavy Combinations

$$\begin{aligned}
 Z &= 50 + 32 + 8 = 90 \\
 Z &= 50 + 32 + 8 + 2 = 92 \\
 Z &= 50 + 32 + 18 = 100 \\
 Z &= 50 + 32 + 18 + 2 = 102 \\
 Z &= 50 + 32 + 18 + 8 = 108 \\
 Z &= 50 + 32 + 18 + 8 + 2 = 110 \\
 Z &= 50 + 32 + 18 + 18 = 118 \\
 Z &= 50 + 32 + 18 + 18 + 2 = 120
 \end{aligned}
 \tag{1}$$

We use the six cycle pattern, with the protons filling in from the outside, and the neutrons filling in between the proton shells towards the center. If we then expand the neutron shells as the nucleus becomes larger and more attraction is needed to stabilize the nucleus, we obtain a geometrical pattern of new shell fillings. This leads to the following possible next "magic" Z numbers beyond 82, where only the outer shells are first filled as the protons get as far away from each other on average as possible.

It is ambiguous to say that all of these are truly magic, and that some new magic numbers may be only two protons apart for Z. The new semi-empirical binding energy fit developed by

Lucas [4] makes no such distinction, so we are really speaking about added binding when sub shells are filled. Lucas uses a "surface" term which counts only the neutrons and protons in the outer sub shell which is near the nuclear surface. He does not have a symmetric "asymmetry" term of the form $(N - Z)^2$. His "pairing" term includes only the sum of the unpaired protons and neutrons. He combines the "asymmetry" and "magic" terms as $(\# \text{ paired neutrons} - \# \text{ paired protons})^2$. The nucleus is becoming crowded, and the number of possible fillings of six shells is becoming limited.

$$\begin{aligned}
 N &= 50 + 32 + 32 + 8 = 140 \\
 N &= 50 + 32 + 32 + 8 + 2 = 142 \\
 N &= 50 + 50 + 32 + 18 + 2 = 158 \\
 N &= 50 + 50 + 32 + 32 = 164 \\
 N &= 50 + 50 + 32 + 32 + 8 = 172 \\
 N &= 50 + 50 + 32 + 32 + 18 = 182 \\
 N &= 50 + 50 + 32 + 32 + 18 + 2 = 184
 \end{aligned}
 \tag{2}$$

Following the same general scheme also leads to the following possible next "magic" N numbers beyond 126, normally leaving the central 2 shell empty. Here we fill in the

next outer shell to a new maximum, to give the nucleus more binding power against the additional outer shell protons in the heavier nuclei.

Note that these purely geometrical shell fillings include all the theoretically proposed new magic numbers except $Z = 106$ and 114 . What is new is that many more possible magic numbers and combinations come to light that have not been examined before against available nuclear data in the medium and heavy nuclei range. We already have many isotopes in the heavy nuclei zone with half lives of millions of years! There may be more at work here besides magic. Neutrons act as glue to hold the protons together, and the optimum amount of glue corresponds to N/Z approximately equal to 1.54 .

Most presently known experimental data on the heavy and superheavy elements is shown in Figure 1 as peninsulas, shoals and islands in the Sea of Instability. We see that the lower end of the Peninsula is near $Z = 90$ and $N = 140$, while the upper end of the Peninsula is near $Z = 100$ and $N = 158$. This represents most of the long-lived red-black band. The low end of the green area is near $Z = 82$, while the upper end of the green area is around $Z = 108$. Can all this be coincidence, since no fancy theoretical modeling was used, only a geometrical pattern of filling 3D space in a symmetric way?

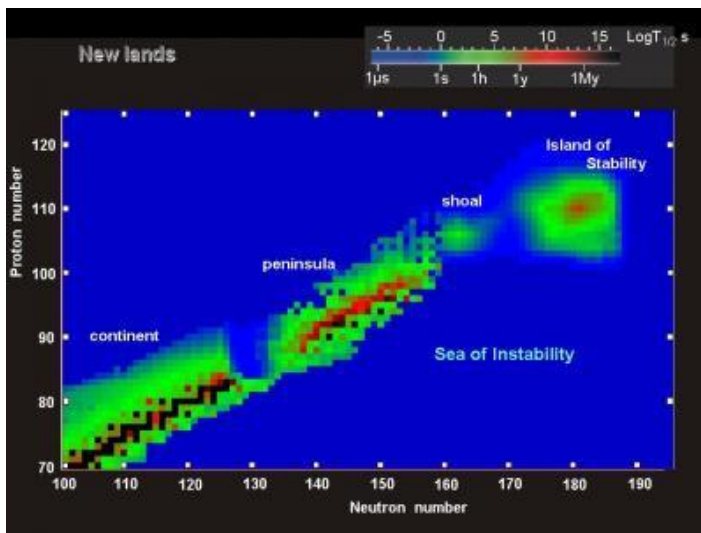


Fig. 1. The Heavy and Experimentally Discovered Superheavy Elements [12]

The Shoal is near $Z = 108$, and it lies between $N = 158$ and 164 . The Shoal is probably part of the Peninsula. The Island of Stability is centered with a red area near $Z = 108$ and $N = 182$, while Z lies between $Z = 102$ and 116 , and N lies between $N = 172$ and $N = 184$. The highest Z discovered Isotope to date is $Z = 118$, although $Z = 120$ is being sought.

5. Examination of the Peninsula

Since magic numbers were never before proposed for Z between 82 and 126 , and the composite sub shell nature of the currently accepted magic numbers was unrecognized, it becomes pertinent to examine what consequences new single and double magic might have on the pattern of known isotopes in the Peninsula area of heavy nuclei. The available data are

summarized in the Table of Isotopes [14], and newer data in the ENSDF database.

The next two proposed doubly magic nuclei using the new shell closing scheme, correspond to Thorium-230, taking $Z = 90$, $N = 140$, and Thorium-232, at $N = 142$! There are 19 known isotopes of Thorium, ranging from Th-218 to Th-237. Th-218 has a half life of nanoseconds, and then the half lives range up to minutes for Th-226 and days for Th-227. These isotopes come mostly from alpha decay of heavier isotopes. Th-229, one isotope short of doubly magic has a half life of 7340 years. Th-230 has a half life of 75,380 years, followed by Th-231 at 25 hours. Th-232 has a half life of $1.4E10$ years. The heaviest four Thorium isotopes up to Th-237 then have half lives of days to minutes. These results seem to confirm the assertion that Th-230 and Th-232 are doubly magic, if long half lives are the primary criteria. Perhaps relatively long half lives is a better criterion. Both have an N/Z of approximately 1.54 which helps stability. The most proton rich isotopes have the shortest half lives, so having extra protons is worse than having extra neutrons.

Next, we examine Uranium which is also possibly magic at $Z = 92$. There are 20 known Uranium isotopes, ranging from U-222 to U-242. The first ten have half lives from microseconds to days. U-232 is possibly doubly magic with $N = 140$, and has a half life of 68 years. U-233 has a half life of $1.6E5$ years, followed by possibly doubly magic U-234 with $N = 142$ at $2.45E5$ years. U-234 is a known longer-lived exception to the Seaborg spontaneous fission correlation for even- Z , even- A nuclei [5]. However, the next two isotopes are also long lived, U-235 has a half life of $7.15E5$ years and U-236 has a half life of $2.4E7$ years. The next isotope has a half life of days, while U-238 has the longest half life of $4.5E9$ years and $N/Z = 1.52$. The last three isotopes have half lives from days to minutes. Obviously, more than magic is involved in this pattern, although magic is clearly playing an important part.

There are a number of other long lived isotopes that are heavier than Uranium, and which also need to be examined. The pattern of Neptunium and Plutonium isotopes is somewhat similar to the pattern for Uranium, except that the long lived isotopes do not closely correspond to magic numbers. The most striking observation is that the long lived isotopes all lie at a ratio of N/Z near 1.54 . This represents the middle of the N versus Z plot shown in Figure 1.

The alpha particle is the most tightly bound nucleus with a binding energy per nucleon of about 7 MeV. As we increase A , the binding energy per nucleon begins to approach this value near $A = 260$, which makes the Q values for alpha decay begin to exceed the Q values for beta decay, thus making alpha decay the preferred mode of decay. At the same time, half lives decrease as Q values increase, so perhaps it is unreasonable to expect long half lives of millions of years for high A isotopes.

Another consideration is spontaneous fission. Seaborg [5] stated that odd- A nuclei were more stable to spontaneous fission than even- A nuclei, and that the criterion for spontaneous fission depended on the fission parameter $Z^2/A > \sim 44$. This makes spontaneous fission the preferred mode of decay for the proton rich heavy and superheavy isotopes.

Fermium is element 100, which is at the next possible magic Z number. It has 19 known isotopes. Fm-242 has a half life of 0.8 milliseconds, and isotopes up to Fm-250 have half lives of seconds to minutes. Isotopes up to Fm-256 have half lives of hours to days. The longest lived isotope is Fm-257 with a half life of 100 days. The next higher isotope is Fm-258, which would possibly be doubly magic at $N = 158$ with a spontaneous fission half life of $37\mu\text{s}$. This is an obvious exception, and it is followed by two more isotopes with half lives of seconds and milliseconds. The process of fission is physically different from alpha decay, so that may be part of the explanation. Perhaps magic is the reason for the existence of so many isotopes of Fermium.

Nobelium is element 102, which is at the next possible magic Z number. It has 12 known isotopes. No-250 has a half life of 0.25 milliseconds. Isotopes ranging from No-251 to No-257 have half lives in the range of seconds to minutes. No-259 has the longest half life of 58 minutes, and then the heavier isotopes are in the range of milliseconds, with No-260 possibly being doubly magic at $N = 158$, but it decays by spontaneous fission. Again, perhaps magic is the reason for the existence of so many isotopes of Nobelium.

6. Reconsideration of Middle Range Isotopes

Since new possible magic neutron numbers below 126 are suggested by the proton number sequence, it is useful to examine a few suggested isotopes to see if magic effects become evident. If we take $N = 90, 100$ and 118 as possible new magic neutron numbers, and use a ratio $N/Z = 1.54$ to obtain the corresponding Z , we are led to examine the isotopes Cerium at $Z = 58$, Dysprosium at $Z = 66$, and Osmium at $Z = 76$ as representative candidates.

Cerium has about 20 known isotopes, going from ^{133}Ce to ^{151}Ce . The major stable isotope is ^{140}Ce , magic at $N = 82$, accounting for almost 90% of natural Cerium. It is interesting that ^{148}Ce , at $N = 90$ with a half life of 56 seconds, and ^{150}Ce at $N = 92$ with a half life of 4 seconds are among the heaviest Cerium isotopes known, suggesting that their very existence is due to magic closing of secondary shells.

Dysprosium is another very interesting element, having almost 30 known isotopes ranging from ^{141}Dy to ^{169}Dy . Five isotopes, from ^{160}Dy to ^{164}Dy , comprise most of the naturally stable isotopes. However, ^{158}Dy , with a magic $N = 92$, and ^{156}Dy , with a magic $N = 90$, are also stable. ^{148}Dy , with a magic $N = 82$, has a half life of 3.1 minutes, while the other lighter Dysprosium isotopes have half lives of the order of seconds. On the heavy end of the isotope sequence are ^{166}Dy , with a magic $N = 100$ and a half life of 81.6 hours, and ^{168}Dy , with a magic $N = 102$ and a half life of 8.7 minutes. The very large number of Dysprosium isotopes meeting conditions of possible magic numbers seems more than coincidental.

Finally, we look at Osmium, which has more than 30 known isotopes ranging from ^{164}Os to ^{196}Os . The naturally occurring Osmium isotopes lie between ^{192}Os and ^{187}Os . Among the lightest Osmium isotopes are ^{166}Os , with a magic $N = 90$ and a half life of 7.1 seconds, and ^{168}Os , with a magic $N = 92$ and a half life of 2.2 seconds, below which the half lives are very short. The next interesting isotopes are ^{176}Os , with a magic $N = 100$ and a

half life of 3.6 minutes, and ^{178}Os , with a magic $N = 102$ and a half life of 5 minutes. Somewhat surprising are ^{184}Os , with a magic $N = 108$ and a half life of $5E13$ years, and ^{186}Os , with a magic $N = 110$ and a half life of $2E15$ years. Finally, on the heavy end we have ^{194}Os , with a magic $N = 118$ and a half life of 6 years, and ^{196}Os , with a magic $N = 120$ and a half life of 35 minutes. Again, the very large number of Osmium isotopes meeting conditions of possible magic numbers seems more than coincidental. The neutron rich isotopes are also more stable than the proton rich isotopes.

We are forced to conclude that the closing of new sub shells is an important factor in allowing the existence of so many of these isotopes.

7. Conclusion

Finding new "magic" numbers as geometrical combinations of only six shell fillings makes sense qualitatively, and gives results not far from similar shell closings predicted with complicated theoretical models. The theoretical models use fits to known structure and other measured data. Indeed, the newly suggested doubly magic numbers are a combination of the different ways that protons and neutrons act, plus the possibility of symmetrically filling 3D space. These new combinations need to be confirmed.

In a not too surprising way, the next possible shell closings are somewhat different for protons and neutrons, because of the different way they react to forces. There are many more ways of filling a shell with less spacing between the magic numbers. This is because the nucleus is becoming filled with nucleons, requiring more difficult force balances, while the possibilities for filling shells are becoming restricted. Experimental evidence indicates that the nuclear density in the centers of heavy nuclei decreases with increasing size [11], indicating spread towards the outside.

When we speak of a sub shell, it is not a spherical surface located at a fixed radius from the center of the nucleus. Rather, it is an annular band in which the nucleons are located as symmetrically as possible in order to produce a static force balance. The protons and neutrons in a given band can geometrically overlap to some extent, and the position and thickness of a band can vary as the nucleus gets larger. In principle, these positions can be verified using a computer code such as developed by Boudreaux and Baxter [15], who used such a code to verify a few light nuclei. Unfortunately, the code would have to be modified to add polarization, re-dimensioned to treat the heavy nuclei, and the iterative variational procedure would have to be verified for numerical stability.

Electron shell fillings have been proposed for 117: Ununseptium, as shown in Figure 2 taken from Wired Science [16]. They use the same general starting pattern of 2, 8, 18, and 32, and then deviate in the outside shells because of the central nucleus attraction which causes electrons to fill from the center out [12]. Inside the nucleus, the protons would be subject to strong repulsion. We contend that the protons would fill towards the center with large full shells on the outside. We would use the pattern 17, 18, 32, and 50 for Z , with an empty center and place extra neutrons in the outside shells to hold the nucleus together.

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117: Ununseptium **2,8,18,32,32,18,7**

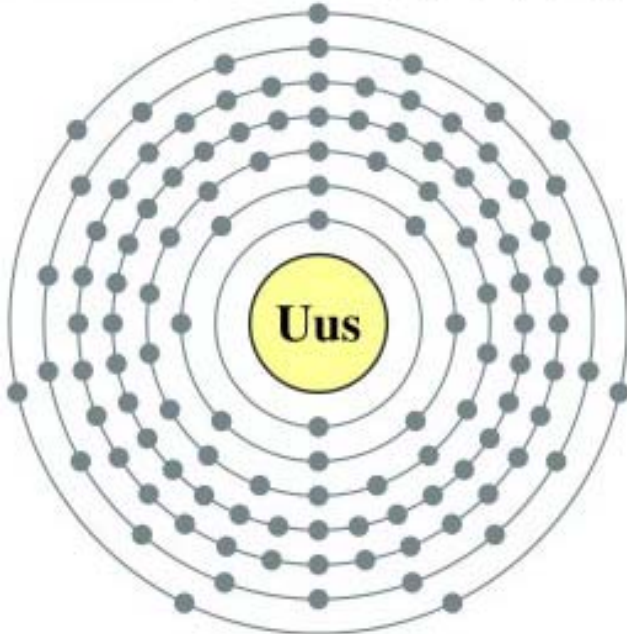


Fig. 2. Element 117 Electron Filling

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