cubic ellipsoid nucleus - part 8: magic numbers of protons

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Abstract

This paper examines the nuclear magic numbers for protons in the light of the cubic ellipsoid nuclear model [3].
Main claim is that if there is a structure that is characteristic of magic numbers, it is a nuclear shape that is more cubic and less round and perhaps also that the nucleons are partly arranged in subgroups of alpha particles.

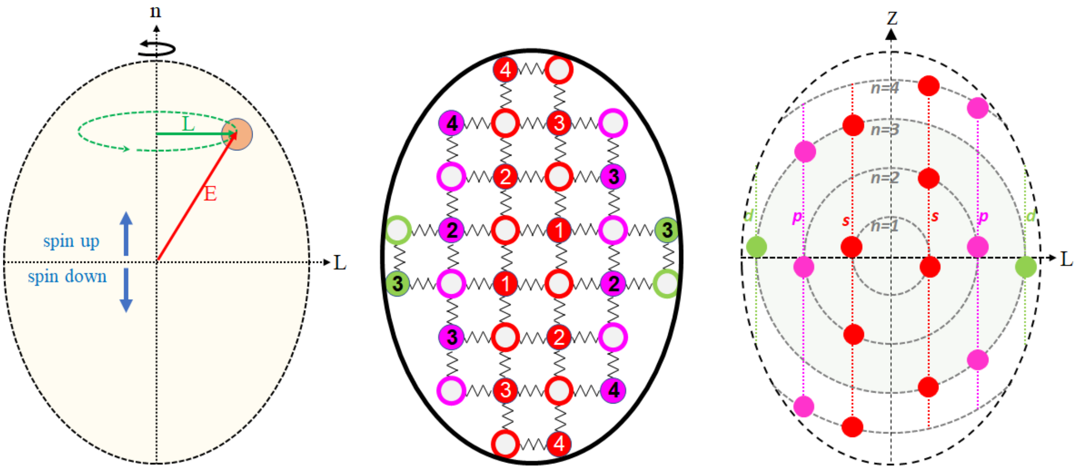
Content

The model at a glance

According to the model these are the shape and properties of the nucleus:

- the nucleus has an ellipsoid shape.
- the nucleon bonds build a cubic system.
- protons are connected to neutrons (**p-n**).
- neutrons are connected mainly to protons.
- the protons are populated and organized in shells in the nucleus in analogy to those of the electrons in the atom.
- the energy layers (principal quantum number **n**) grow with the distance from the origin.
- the perpendicular distance from the **z**-axis in the **x-y**-plane reflects the angular momentum (**L**, sub-orbitals).
- the upper half of the ellipsoid is referred to as spin-up and the lower part as spin-down.
- the nucleus possibly rotates around its **z**-axis.

The following drawings describe the idea via cross sections in the **x-z**-plane of the nucleus.

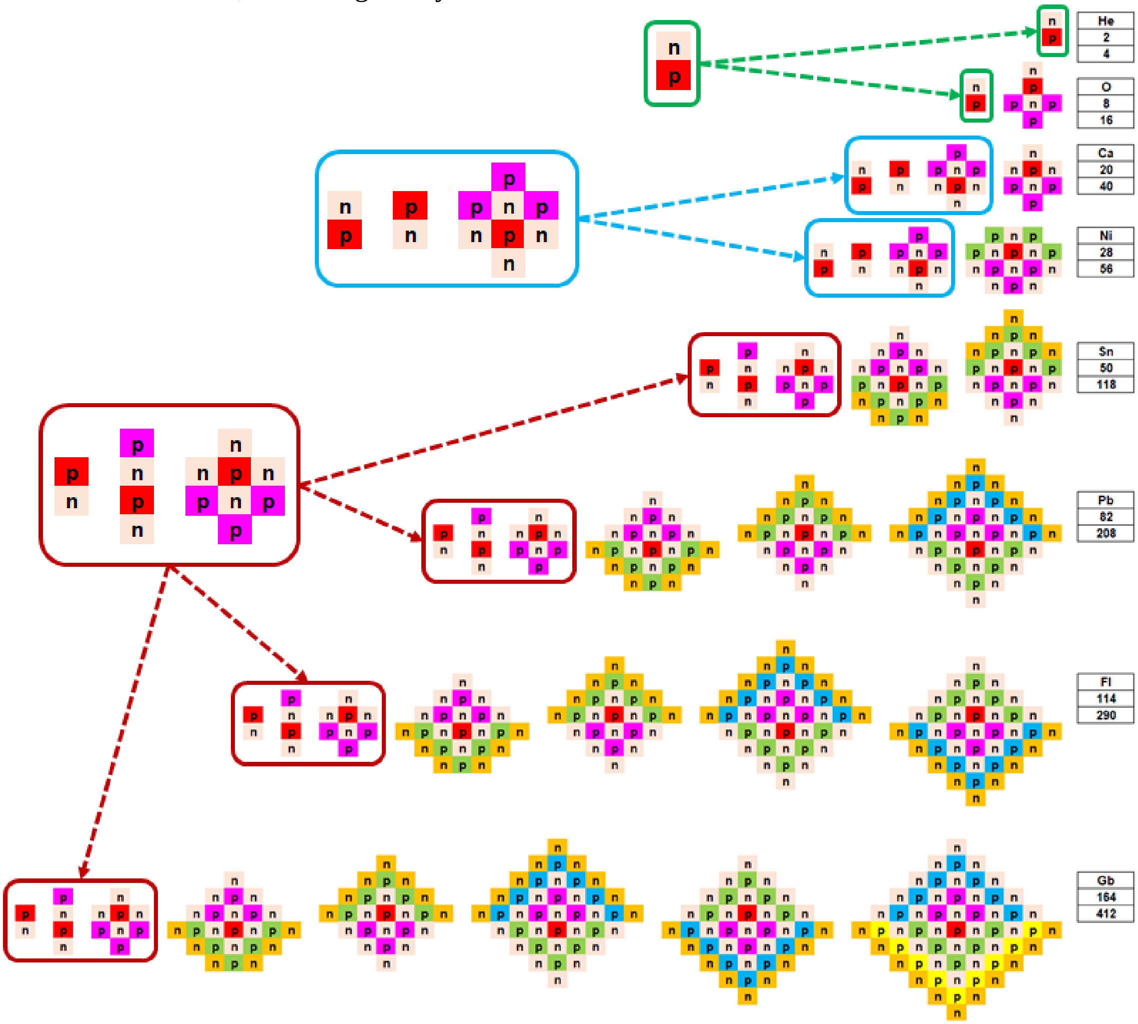


***1**: a nucleon in the nucleus* — ***2**: the bonds between the nucleons* — ***3**: the energy levels of the nucleus*

1. a nucleon (**circle**) is observed inside the ellipsoid (dashed line) that encloses the nucleons and schematically defines the nuclear surface:
   - the distance from the origin represents its energy **E**.
   - the distance from the **z**-axis depicts it angular momentum **L**.
   - the nucleons in the upper half have spin-up, and in the lower one spin-down.
2. the bonds between the nucleons are shown for visibility as springs.
   - **protons**: full circles of the **s**, **p** and **d** sub-orbitals. **neutrons**: hollow circles.
3. the circles of equal energy states **n** in the ellipsoid.
   - the lines mark the development of the **s**, **p** and **d** sub-orbitals along the **z**-axis.
   - the **s** line crosses all **n** circles from 1 to 4 (**s1** to **s4**).
   - the **p** line begins by **n**=2 and reaches till **n**=4 (**p2** to **p4**).
   - the **d** line begins by **n**=3 and reaches the ellipsoid border, before it reaches the **n**=4 circle, and therefore there are no **d4** states at this stage (only **d3**).

The nuclear magic numbers for protons

Nuclei with magic number of nucleons (either protons or neutrons) are more stable than others; according to the nuclear shell model this phenomenon is due to closed nuclear shells. We try to interpret it according to our model and refer in this research only to the magic numbers of protons. According to the model we could expect that the nuclei of magic numbers will be the ones of the noble gases with their closed shells, but this isn't the case. The layers of the nuclei of the noble gases are relatively round with a continuous change or slope while moving along its envelope, yet this does not necessarily mean, that their nuclei are stronger bound.
The magic numbers for protons are: 2, 8, 20, 28, 50, 82 [1] this corresponds to the nuclei: He, O, Ca, Ni, Sn, Pb. We try to explain it under the assumption, that the more the nuclei have a "cubic" form, the stronger they are bound.



Legend: p - protons *according to the orbitals* ***S***, ***P***, ***D***, ***F***, ***G***. ***n - neutrons, n - excess***.
for visibility only the left (or upper) half of the nucleus is shown

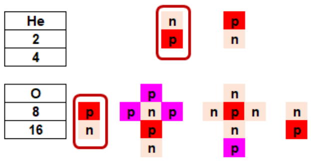
In the last two lines we continued with the same pattern to get the expected magic numbers of Flerovium Fl_{114} and of the predicted element Unhexquadium Uhq_{164} (or Gibbsium Gb_{164}). According to the model Gb_{164} is expected to be extremely unstable [4] and therefore probably cannot exist.

Analyzing the nuclei with magic number of protons

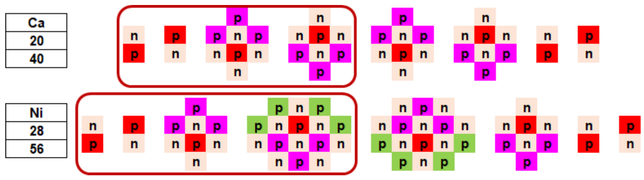
We look for features that distinguish the nuclei with magic number of protons and divide them in two groups according to their pattern.
Two hypotheses are raised here for the source of their stronger bonds:

1. their shape is more cubic, and less round.
2. their nucleons may be partly organized in subgroups of alpha particles.

First group
Helium He_2, Oxygen O_8, Calcium Ca_{20}, Nickel Ni_{28}.



- Helium He_2: perfectly fulfill both hypotheses: cubic and organized as alpha particle.
- Oxygen O_8: is cubic, partly ordered in groups of alpha particles and is a multiple of alpha particles.



- Calcium Ca_{20}: (like Helium and Oxygen) Calcium is arranged in perfect alpha groups.
- Nickel Ni_{28}: can't be fully organized in groups of alpha particles; yet it has a cubic shape.

Additional properties:

- Helium and Calcium close an **S** sub-orbital.
- Oxygen and Nickel lack two protons that close the next sub-orbital:
  - Oxygen lacks two protons to fill the **P** sub-orbital.
  - Nickel lacks two protons to fill the **D** sub-orbital.

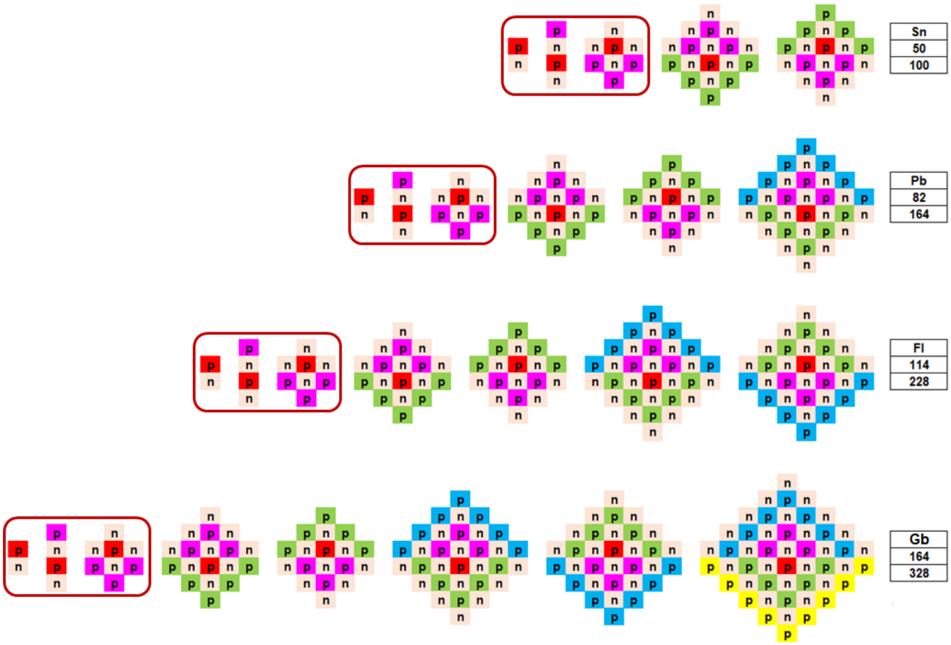
Remarks:

- for visibility the excess neutrons are not shown.
- Oxygen possibly has another configuration, which is cubic with complete subgroups of alpha particles, but we assume, due to studies that follow this one, that the configuration here is probably the more correct one.

Second group

Tin Sn_{50}, Lead Pb_{82}, Flerovium Fl_{114}, Unhexquadium Uhq_{164} (or Gibbsium Gb_{164}).
They all have the same pattern:

- their current sub-orbital is **P**.
- they are missing four protons from the next noble gas.
- the three outermost layers are of the same type, i.e. more cubic and less round.
- all inner layers can form complete alpha particles.



Remarks: for visibility:

- only the left (or upper) half of the nucleus is shown.
- the excess neutrons are not shown.

Discussion of the results and conclusion

Our model doesn't predict the magic numbers, but we tried in this research to find the characteristics of the nuclei that represent this phenomenon in order to avoid contradictions between our model and the nuclear shell model.
The results were the assumptions that two properties possibly distinguish the nuclei with magic number of protons:

1. their shape is more cubic, and less round.
2. their nucleons may be partly organized in subgroups of alpha particles.

This isn't a proof of the concept, but only an idea on how to approach the subject.

Sources and references - part 8

1. *Magic number (physics) - (Wikipedia)*
2. *The Magic Is Gone for Neutron Number 32 - (energy.gov)*
3. *cubic ellipsoid nucleus - part 1 - the model and its mass formula - Ronen Yavor*
4. *cubic ellipsoid nucleus - part 5 - instability of heavy elements - Ronen Yavor*