cubic ellipsoid nucleus - part 7: Abundance of the elements

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Abstract

This paper examines the Abundance of the light elements, from Helium till Neon, in the light of the cubic ellipsoid nuclear model [12].
The result is that the abundance of an element depends mainly on the following:

- a nuclear up-down and left-right symmetry.
- an even number of protons and even number of neutrons.
- total spin is zero.

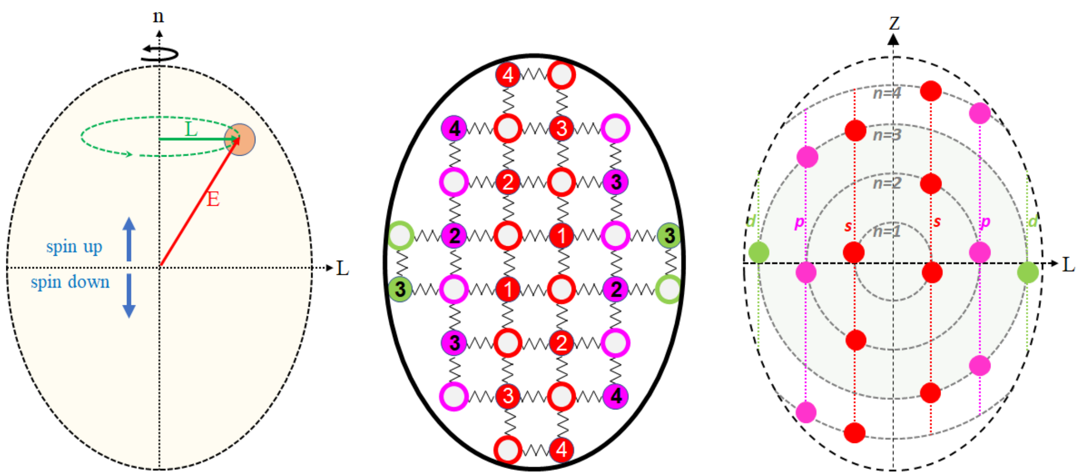
Content

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.



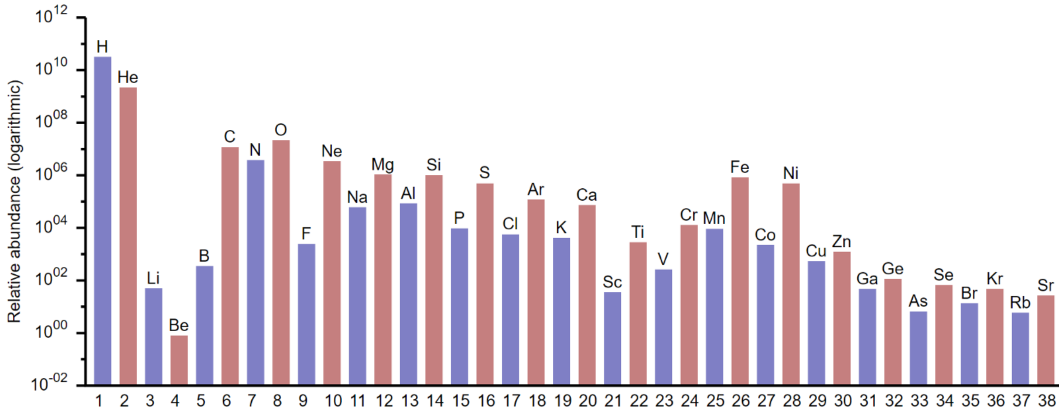
***1**: a nucleon in the nucleus*   ***2**: the bonds between the nucleons*   ***3**: the energy levels of the nucleus*

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**).

Introduction

The table of the abundance of the elements shows the following:

- The abundance decreases in general from left to right.
- The abundance of nuclei with an even number of protons is in general larger than their next neighbors (on both sides) with an odd number of protons.
- The abundance of Lithium, Beryllium and Boron is much smaller than what could be expected from the general shape of the table.
- The abundance of Beryllium is, in addition to the last paragraph, much smaller than Lithium and Boron, which is also unexpected for a nucleus with an even number of protons.
- The abundance of Nitrogen is large relative to an element with an odd number of protons.
- The abundance of Fluorine is low relative to the expected value, which should be somewhat between the values of Nitrogen and Sodium.



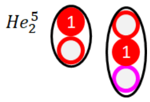
estimated abundances of the elements in the Solar System (logarithmic scale) [2].

In the following we will describe this for the nuclei from helium to neon and discuss various phenomena related to these nuclei.

Why a nucleus with five nucleons is unstable?

Possible candidates for a nucleus with five neutrons are He_2^5 and Li_3^5.

Helium - He_2^5

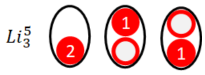


We begin from the stable nucleus of He_2^4, that has:

- a perfect up-down and left-right symmetry.
- an even number of protons.
- an even number of neutrons.
- total spin equals zero.

An extra neutron causes the transition from He_2^4 to He_2^5; this additional neutron breaks most of the properties mentioned above, and so a significant decrease of the nuclear stability is expected.

Lithium - Li_3^5

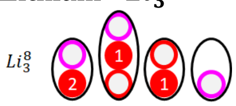


Li_3^5 has too many protons or not enough neutrons to stabilize it and, unlike He_2^3, it has no symmetric structure, so it is not expected to be stable.

Why a nucleus with eight nucleons is unstable?

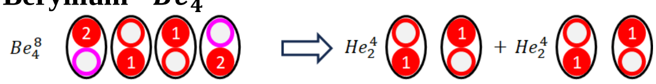
Possible candidates for a nucleus with eight nucleons are Li_3^8 , Be_4^8 and B_5^8.

Lithium - Li_3^8



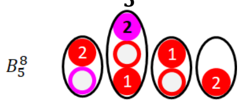
The Li_3^8 nucleus has a poor symmetry with too many neutrons relative to the number of protons, so it is expected to be unstable.

Beryllium - Be_4^8



The Be_4^8 nucleus is expected to split into two He_2^4 nuclei, which are very stable.

Boron - B_5^8

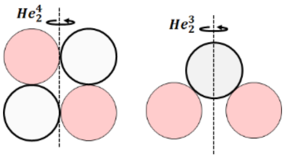


The B_5^8 nucleus has poor symmetry and too many protons relative to the number of neutrons. It is therefore unstable and is likely to lead to proton emission.

The abundance of the light nuclei

This chapter discusses the abundance of each nucleus from helium to neon, while considering its structure according to the model.

Helium



He_2^4 and He_2^3 have a symmetric structure.

- He_2^4 : (99.9998%) is very stable, due to its:
  - perfect up-down and left-right symmetry.
  - an even number of protons and neutrons.
  - total spin is zero.
- He_2^3 : (0.0002%) has a very low abundance, because it has:
  - more protons than neutrons.
  - an odd number of neutrons.
  - total spin $\frac{1}{2}$.

  Yet He_2^3 can reach symmetry if rotated in 45 degrees, and this possibly explains its stability.

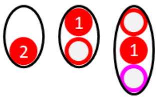
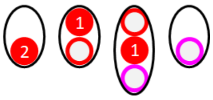
Lithium, Beryllium, Boron

All three are less abundant than what could be expected from the shape of the table.
According to the model this could be due to their:

- low symmetry: because of the small number of nucleons, each additional nucleon has a relatively large influence on the symmetry, forces and geometry resulting in less stable nuclei.
- long and thin shape: as a result, the center of these nuclei possibly exerts less force to hold the nucleons together.

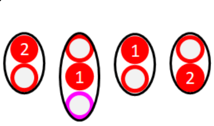
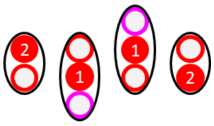
Specific discussion of their nuclei:

Lithium

Li_3^6  Li_3^7 

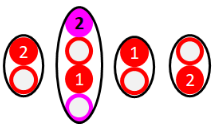
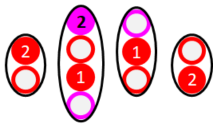
- Li_3^6 (5%) has a poor symmetry with spin $I = 1$ and is possibly therefore less stable.
- Li_3^7 (95%) has a poor symmetry with spin $I = \frac{3}{2}$ and is possibly therefore less stable.
- The Li_3^7 is more symmetric than Li_3^6 due to its excess neutron and is possibly therefore more abundant.

Beryllium

Be_4^9  Be_4^{10} 

- Be_4^9 : (100%) has poor symmetry, which makes it less stable and this could be an explanation for its low abundance. The excess neutron is required to stabilize the protons and to avoid a decay to two alpha particles.
- Be_4^{10} : (trace) is symmetric and has an even number of protons and neutrons and total spin zero. Its low abundance could be due to the relatively large number of neutrons compared with the number of protons, that could cause a neutron β decay to create Boron B_5^{10}.

Boron

B_5^{10}  B_5^{11} 

- B_5^{10} : (20%) has a low symmetry and is therefore less abundant.
- B_5^{11} : (80%) is more symmetric than B_5^{10} making it the more abundant isotope of Boron. Nonetheless also this configuration has a poor symmetry and is relatively long and thin, so it is possibly therefore less abundant.

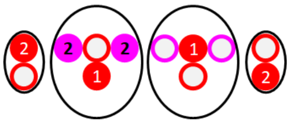
Carbon, Nitrogen, Oxygen, Fluorine, Neon

We consider the nuclei of C, N, O, F and Ne.
C, N and O have different potential nuclear configurations.
We select the nuclear structure that we believe is more likely to be the correct one, taking into account the following points:

- The total symmetry of the nucleus (up-down and left-right).
- The total nuclear spin.
- The total nuclear mass, that depends on the number of nuclear bonds.

Carbon

C_6^{12}



Legend: protons*: full circles according to the orbitals* ***S***, ***P***, ***D***, ***F***. ***Numbers****: energy levels.*
neutrons*: hollow circles with colors according to their orbital.*

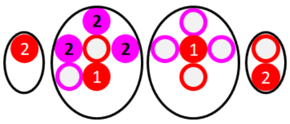
Requirements fulfilled:

- a total spin equals zero.
- an equal number of nucleons with spin-up and spin-down.
- an up-down and left-right symmetry.

This explain its high abundance.

Nitrogen

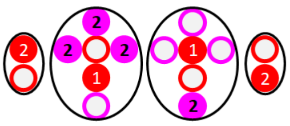
N_7^{14}



Nitrogen has a total nuclear spin I=1, yet it has an equal number of nucleons with spin-up and spin-down and is almost up-down and left-right symmetric, so maybe therefore its abundance is relatively high for an element with an odd number of protons.

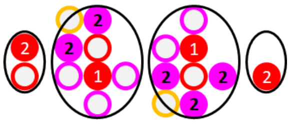
Oxygen

O_8^{16}



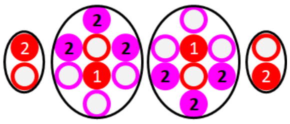
has a total spin zero, a left-right and up-down symmetry and, in addition, the number of protons and neutrons is a multiple of helium nuclei and this may add to its stability, so we would expect its abundance to be high.

Fluorine

F_9^{19} 

has total spin I= $\frac{1}{2}$, in addition it has neither left-right nor up-down symmetry, so this might be the explanation to its low abundance relative to its neighbors with odd number of protons, Nitrogen and Sodium.

Neon

Ne_{10}^{20} 

has a high up-down and left-right symmetry and its layers are complete, making it very stable, so a large abundance is expected.

Discussion of the results and conclusion

We see that the abundance of the elements depends on the stability requirements:

- maximum symmetry.
- stability of proton and neutron configurations.
- nuclear spin (which is a result of the above).

and draw the conclusions that:

- an even number of protons and neutrons leads to larger stability.
- if the number of protons and neutrons is equal, the stability increases.
- up-down and left-right symmetries increase the nuclear stability.
- nuclei with odd number of protons and neutrons are more stable if they are symmetric.
- small changes of the nuclear configuration affect smaller nuclei more than large ones, because the relative change is greater.

This explains the following:

- the high abundance of Helium.
- instability of nuclei with five or eight nucleons.
- the low abundance of Lithium, Beryllium and Boron.
- the large abundance of Carbon, Oxygen and Neon.
- the abundance of Nitrogen that is large relative to a nucleus with an odd number of protons.
- the abundance of Fluorine that is low relative to what is expected from the shape of the table.

Remark: although the determination of the nuclear configuration is not conclusive, the difference in outcome between the various configurations is not large, so it seems that the exact configuration is not critical for the purpose of this initial discussion.

Sources and references - part 8

1. *Tables of Nuclear Data: Japan Atomic Energy Agency (JAEA)*
2. *Abundance of the chemical elements - Wikipedia*
3. *Isotopes of helium - Wikipedia*
4. *Isotopes of lithium - Wikipedia*
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6. *Isotopes of boron - Wikipedia*
7. *Isotopes of carbon - Wikipedia*
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9. *Isotopes of oxygen - Wikipedia*
10. *Isotopes of fluorine - Wikipedia*
11. *Isotopes of neon - Wikipedia*
12. *cubic ellipsoid nucleus - part 1 - the model and its mass formula - Ronen Yavor*
13. *cubic ellipsoid nucleus - part 4 - nuclear stability and excess neutrons - closed sub-orbitals - Ronen Yavor*