Alpha Particle Structure of Nucleus

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Nuclear Structure Theories
Experimental evidences for the existence of magic numbers

- 2, 8, 20, 28, 50, 82, and 126

1. Large binding energy

2. Stable isotopes

3. Abundance

4. Naturally occurring radioactive series decay to the stable end product Pb with $Z=82$ in three isotopic forms having $N=126$ for one of them.
5. Neutron absorbing cross section is very low

7. First excited states is at higher energies

8. Electric quadrupole moment of magic numbered nuclei is near zero indicating the spherical symmetry of nucleus for closed shells.

9. High energy of alpha or beta particles emitted
History

“Just because you see alpha particles coming out of nucleus, you should not necessarily conclude that inside they exist as such.”

E. Schrödinger
Ernest Rutherford (1899)

Alpha particle decay

Wefelmeier (1937)
Wheeler (1937)
Von Weizsacker (1938)

Bethe and Bacher (1936)
Hafstad and Teller (1938)

Fig. 2. Binding energy for saturated nuclei.

Martin Freer (2010)

Graph showing binding energy vs. number of bonds.
Semi-classical Microscopic Approach to the Liquid drop model

Zbigniew Sosin (http://arxiv.org/abs/1304.2846)

$^{12}\text{C}$
$^{16}$O
$^{20}\text{Ne}$
$^{24}\text{Mg}$
$^{28}\text{Si}$
$^{40}\text{Ca}$
Binding energy and number of bonds

![Graph showing the relationship between binding energy (MeV) and the number of bonds, with data points for various elements marked.](image-url)
First Approximation

Binding energy of alpha particle ($^4\text{He}$),

\[ b_\alpha = 28.296\text{MeV} \]

\[ ^{12}\text{C} = 3\alpha \]

\[ B(^{12}\text{C}) = 92.163\text{MeV} \]

\[ 3\alpha = 84.888\text{MeV} < B(^{12}\text{C}) \]

\[ B = n_\alpha \times b_\alpha + n_b \times b_{\alpha-\alpha} \]

\[ b_{\alpha-\alpha} = 2.425\text{MeV} \]
From Zn, Bethe’s prediction changes

1 center $\alpha$ bond energy $= 3.264 \text{ MeV}$

2 center $\alpha$ bond energy $= 2 \times 3.264 \text{ MeV} = 6.528 \text{ MeV}$
Bond length and bond energy

![Graph showing bond length and bond energy]
\[ b_{4n+2} = b_{4n} + 12.498 \text{MeV} \]
Structure of nuclei heavier than Sn

Color lines are the experimental binding energy for all nuclei. Same color shows the isotopes of same nuclei.
Structure of nuclei heavier than Sn
Alpha Particle structure of nuclei

- Experimental Data up to Sn-100
- As a sum of Sn-100 + the next light nuclei
Alpha Particle structure of nuclei?
Fission Fragment distribution
More evidences!!

Density distribution

Giant Dipole Resonance (GDR)
Results and Conclusion

• Structural change from Zn is the reason for the abundance of Iron peak elements in the Universe

• Alpha particle need high energy to overcome the coulomb energy of balloon like surface to enter inside

• Supernova explosion

• Nuclear fission

• Asymmetric fission

• Symmetric fission
Thank you...