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A Review Study Between 1st Ionization Potential And Binding Energy Of The Last Proton For Atomic Magic Numbers And Magic Number Nuclei Of Atom.

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Abstract: *In the present paper there will be a study about the 1st ionization potential and the nuclear binding energy of atoms having atomic magic numbers (inert gas atoms) and nuclear magic numbers, hence the binding energy of the last proton with the help of nuclear single particle shell model. Ionization potential and 1st ionization potential of atomic magic numbers are very high compared to the ordinary atoms. On the other hand in an atom having magic number of nucleon either proton or neutron or both are more stable nucleus i.e. higher values of nuclear binding energy compared to their nearest neighbours. But these two extraordinary behaviours are not observed in the same atom. Helium is a special case.*

Introduction:

It is well known from basic science that when the total no electrons in an atom are 2, 10, 18, 36, 54, 86 electrons form complete shells and sub-shells, as a result electronic bindings are very high i.e. much more energy require to remove electron from the shell, hence their ionization potential and 1st ionization potentials are very high compare to the other atoms. These are called atomic magic number (inert gases). He Ne, Ar, Kr, Xe, Rn are called atomic magic number atom. The energy require to supply to remove first electron from the atomic shell is called 1st ionization potential.

On the other hand when the number of nucleons are 2,8,20,50,82,126 (either protons or neutrons) are more stable i.e. nuclear binding energy are higher compared to their nearest neighbours. These are called magic number nuclei. ${}_{2}He^{4}$, ${}_{8}O^{16}$, ${}_{20}Ca^{40}$, ${}_{28}Ni^{58}$,${}_{38}Sr^{88}$,${}_{50}Sn^{120}$,${}_{58}Ce^{140}$,

${}_{82}Pb^{208}$ are called magic nuclei. Almost similarly the existence of nuclear magic numbers and their stability as well as their higher binding energy can be explained on the basic of nuclear closed shells with the single particle nuclear shell model. Different shell and sub-shells are considered inside the nucleus and protons and neutrons are separately moving around the centre of the nucleus independently and when nucleon numbers are sufficient to form a closed shell, results higher binding energy compared to their nearest nuclei.

But these two extraordinary properties i.e. higher stability of electrons and nucleons are observe for different atoms.

Theory and Calculation:

Ionization Potential (I.P).

1st Ionization potential of atomic magic atom is the amount of energy (in eV) required to remove first electron from the last closed shell. But for nuclear magic atoms it is the energy required to separate the electron from the last unfilled shell. 1st ionization potential can be estimated with the standard formula for both the cases. For the calculation of 1st ionization potential standard formula can be used as

$E_n= Z^2_nE_1/n^2$.where E_1 and Z_n are the ionization potential of Hydrogen and the effective charge that acts on the outer shell electrons respectively (shielding effect are included), n is the quantum no. of the orbit. The effective charge significantly varies for closed shells (i.e. for atomic magic atoms) and uncompleted shells (i.e. magic no. nuclei) and the theoretical calculations are very complicated.

Nuclear Binding energy (B.E):

For the calculation of nuclear binding energy, generally two methods can be applied i) directly from the mass defect estimation and ii) with the help of semi- empirical mass formula (considering liquid drop model of the spherical nucleus).

Binding energy calculation from the mass defect: Nuclear Binding energy = 930 $[1.007841 x Z + 1.008665 x (A-Z) - M_{A\ Z}]$ MeV. A, Z are mass no. and atomic no. of the atom respectively. Mass of proton and mass of neutron are 1.007841 a.m.u and 1.008665 a.m.u respectively, and $M_{A\,Z}$ is the atomic mass.

Binding energy calculation from semi empirical mass formula: Considering the nucleus as a liquid drop the semi empirical mass formula is developed. According the formula the B.E is given by

$B.E=aA - bA^{2/3} - cZ(Z-1)/A^{1/3} - d(A - 2Z)^2/A \pm ð/A^{3/4}$ ----(1), where the successive parts are volume energy, surface energy, coulomb energy, asymmetry energy and pairing energy term. A and Z are the mass no. and atomic no. of the examined nucleus. And a, b, c, d, and ð are constants, their values are 15.752, 17.795, 0.71, 23.6846 and 33.516 MeV. respectively. In the present case as A and Z both are even so the sign in front of ð is positive. With the help of the above mentioned formula, nuclear binding of atomic magic nuclei as well as for magic no. nuclei have been estimated. Finally B.E per nucleon is calculated.

Binding Energy of last Proton: For atomic magic nuclei as well as for nuclear magic nuclei, it is treated as the amount of energy required to get free one proton from the nuclear last shell (with respect to the nucleus it is treated as last proton). For the first case the shell is unfilled and the latter shell is completed. $_2He^4$ is a special case. It can be estimated by the equation $E_p=[m_p+M(Z-1,A-1)-M(Z,A)]x931$ MeV.

1. Table no. 1[Elements (atomic magic no.,1st ionization potentials(I.P), B.E, and B.E/A]

Atomic magic nos.	1st(I.P) in eV	B.E in MeV.	B.E per nucleons in MeV
$_2He^4$	24.580	29.16	7.29
$_{10}Ne^{20}$	21.559	164.17	8.21
$_{18}Ar^{40}$	15.755	351.49	8.79
$_{36}Kr^{84}$	13.996	738.89	8.80
$_{54}Xe^{132}$	12.127	1117.2	8.46

2. Table no. 2[Elements, B.E of the last proton for atomic magic no. atom and (B.E/A)/(ionization potential) and(B.E of the last proton) /(ionization pot.)]

Atomic magic nos.	B.E of the last proton in MeV.	(B.E/A)/(I.P.)x1000	(B.E of the last proton)/(I.P.) x1000
$_2He^4$	19.79	0.297	0.805
$_{10}Ne^{20}$	12.85	0.381	0.596
$_{18}Ar^{40}$	10.06 .	0.558	0.638
$_{36}Kr^{84}$	9.74	0.629	0.695
$_{54}Xe^{132}$	8.45	0.700	0.697

3. When Mass number of atomic magic no. atom is plotted along the X axis and the ratio of binding energy per nucleons to the 1st ionization potential is plotted along Y axis the variation shows in fig 3.

4. Mass number of atomic magic no. atom is plotted along the X axis and binding energy of the last proton is plotted along Y axis the variation shows in fig 4.

5. Variation of the ratio of B.E of the last proton to the 1st ionization potential with mass no. is shown in fig 5.

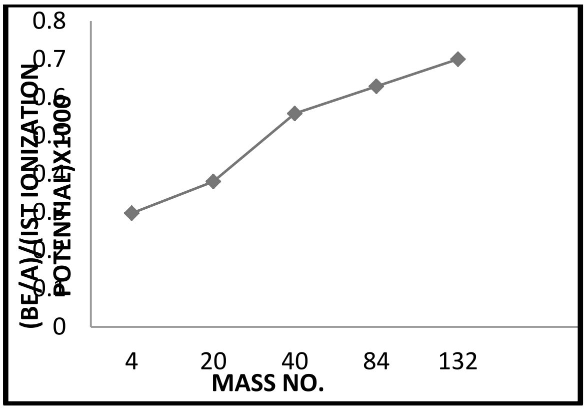

FIG:3

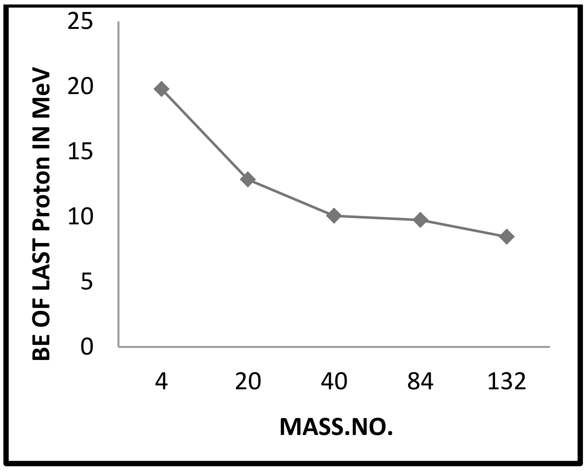

FIG: 4

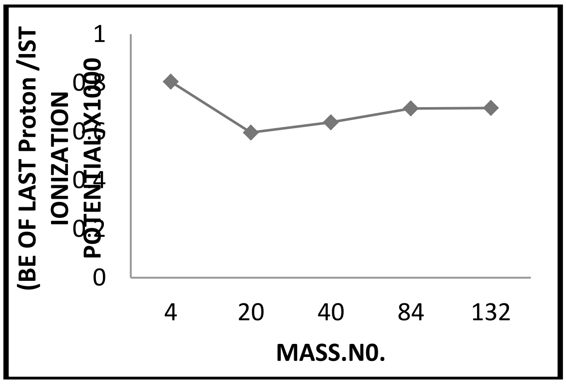

FIG: 5

6. Table no.3[Elements,1st ionization Potentials, B.E, and B.E/A] for magic no. nuclei.

Magic no.Nuclei.	1st(I.P) in eV	B.E in MeV.	B.E per nucleonMeV
$_{2}He^{4}$	24.58	29.16	7.29
$_{8}O^{16}$	13.61	127.65	7.97
$_{20}Ca^{40}$	6.11	337.27	8.43
$_{28}Ni^{58}$	7.63	508.81	8.77
$_{38}Sr^{88}$	5.69	772.80	8.78
$_{50}Sn^{120}$	7.33	1027.03	8.55
$_{58}Ce^{140}$	5.54	1177.65	8.41
$_{82}Pb^{208}$	7.42	1636.75	7.87

7. Table no. 4[Elements, 1st ionization potentials, B.E, B.E/A and B.E of the last proton for magic no. of nuclei.]

Magic no.Nuclei.	B.E of the last proton in MeV.	(B.E/A)/(I.P) x1000	(B.E of the last proton) /(I.P)x1000
$_{2}He^{4}$	19.79	0.297	0.805
$_{8}O^{16}$	12.13	0.586	0.830
$_{20}Ca^{40}$	7.93	1.382	1.297
$_{28}Ni^{58}$	7.35	1.150	0.963
$_{38}Sr^{88}$	10.34	1.564	1.817
$_{50}Sn^{120}$	8.33	1.166	1.136
$_{58}Ce^{140}$	8.12	1.520	1.465
$_{82}Pb^{208}$	8.02	1.060	1.080

8. When Mass number of magic no .nuclei is plotted along the X axis and the ratio of binding energy per nucleons to the 1st ionization potential is plotted along Y axis the variation shows in fig 6.

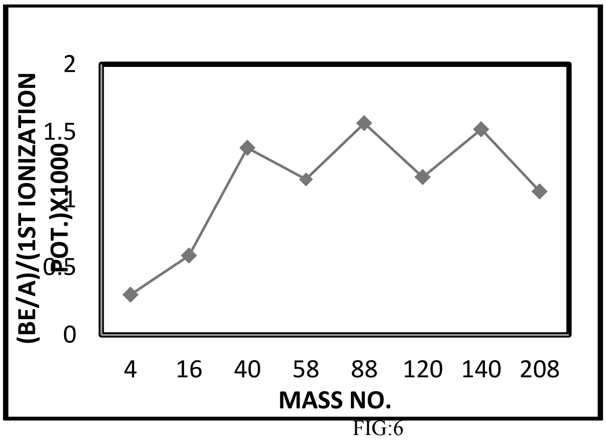

FIG:6

9. Mass number is plotted along the X axis and binding energy of the last Proton is plotted along Y axis the variation shows in fig 7.

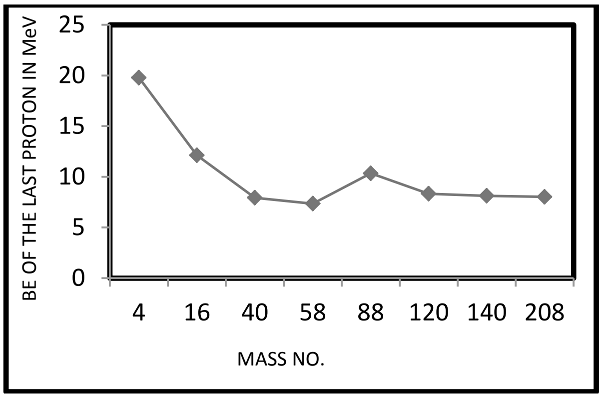

FIG:7

10. Variation of the ratio of B.E of the last neutron to the ionization potential with mass no. of magic no. nuclei is shown in fig: 8.

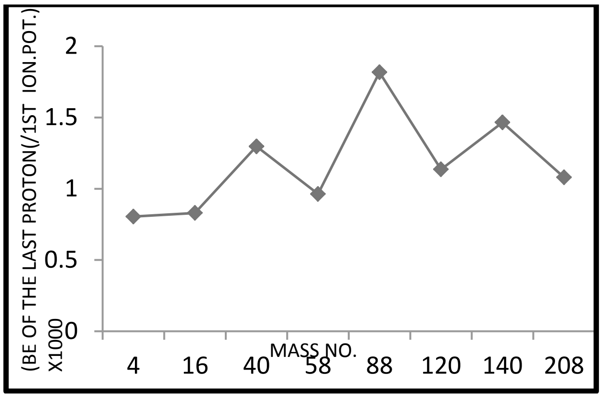

FIG:8

Discussion: It is observed from the obtained results that the binding energy of the last proton is higher than the binding energy per nucleon for atomic magic nos. But it is reverse for He, $O_{2.}$ Sr_{38} and Pb_{82} and also for inert gas atoms, the ratio BE/A to ionization potential increases with mass no. but for magic no. nuclei it is not symmetric. For the variation of BE of the last proton it is always decreases with the mass no. for both the cases and symmetric other than A=88, these are shown in figs 4 and 7 .The ratio BE of the last proton to ionization potential first decreases and then almost constant for inert atoms, it is the least at A=20. For magic nucleus it is increases first and then changes asymmetrically.

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