# Occurrence of new magic number at Z, N = 14, 16

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### Introduction

Appearance of shell gaps between well-defined energy levels of protons and neutrons confirms the magic numbers. The nuclei with magic numbers have an unusual stability than the other nuclei. The advent of new experimental techniques and theoretical works led to the identification of new magic numbers in exotic region. The single particle energy plays an inevitable role in describing the microscopic structure and shell properties of the nuclei. There exist a large gap between the single particle energy levels at the occurence of the magic numbers. The neutron-rich nucleus $^{42}$Si studied using two proton knockout reaction has shown the occurrence of the shell gaps at proton and neutron numbers Z, N = 14 in the exotic region [1, 2]. The investigation of one and two nucleon separation energies using new modified mass formula, have characterized the appearance and disappearance of magic numbers [3]. In the present work, the occurrence of the shell gap at new magic number Z, N = 14 in the exotic region near the drip line is analyzed by studying the single particle energy levels and gap between the levels $1d_{5/2}$, $2s_{1/2}$ and $1d_{3/2}$.

### Methodology

The single particle energies are calculated using [4]

$$\varepsilon(\text{particle}) = \text{BE(core)} - \text{BE(core+n)} \quad (1)$$

$$\varepsilon(\text{hole}) = \text{BE(core-n)} - \text{BE(core)} \quad (2)$$

Here, BE represents the binding energy of the core and core ± nucleon (core±n). Experimental binding energies are taken from Ref. [5] for core and core ± nucleon.

### Results and discussion

In the present work, the binding energies of the selected nuclei are taken from Ref. [5]. Single particle energies of $1d_{5/2}$, $2s_{1/2}$ and $1d_{3/2}$ levels are calculated using the difference between binding energies of core and core ± nuclei as given by Eqs. (1) and (2). Here, both particle and hole are considered while calculating the single particle energies. For example to calculate the single particle energy level $1d_{5/2}$, the core nucleus is $^{22}$Si and its adjacent nucleus is $^{23}$Si, which is the core

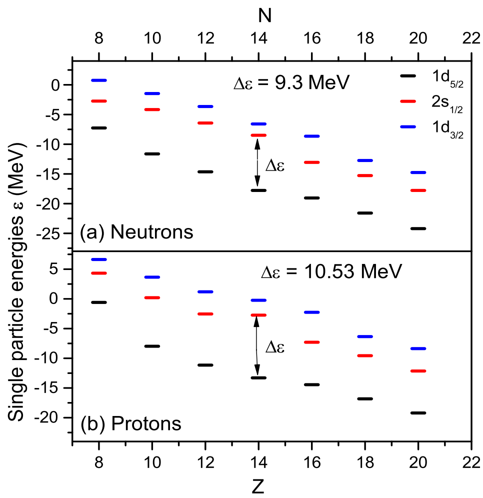


FIG. 1: Single particle energy levels calculated for the nuclei from O to Ca

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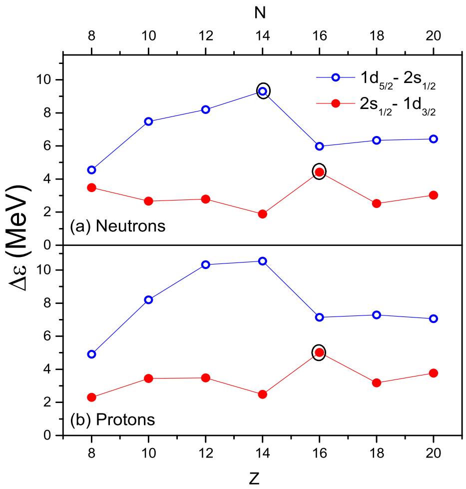


FIG. 2: Difference in the single particle energy levels calculated for the nuclei from O to Ca

+ nucleon (particle). Hence the particle (neutron) energy is considered. The binding energies of these nuclei are 132.968 MeV and 150.742 MeV respectively. The difference between the calculated binding energies of these two nuclei is -17.774 MeV. For $2s_{1/2}$, the nuclei $^{28}$Si and $^{29}$Si are considered for core and core + nucleon. The energy is - 8.473 MeV. For $1d_{3/2}$, $^{30}$Si and $^{31}$Si are considered for core and core + nucleon and single particle energy is -6.587 MeV. The isotopes and isotones with Z, N between 8 and 20 are considered, to calculate SPE of $1d_{5/2}$, $1d_{3/2}$ and $2s_{1/2}$, to study the occurrence of the shell gaps at Z, N = 14, 16.

In Fig. 1, the lowest lines (black) represents the $1d_{5/2}$ energy levels, the middle lines (red) indicates $2s_{1/2}$ and the lines at top (blue) indicates $1d_{3/2}$ levels in each panel. Fig. 1 (a) shows the single particle energies (SPE) calculated for isotopes. A large gap between $1d_{5/2}$ and $2s_{1/2}$ levels is noted, particularly at N = 14 and their difference is about 9.3 MeV. $\triangle\varepsilon(1d_{5/2}$ - $2s_{1/2})$ is found to be large at N =14 than the differences at N = 8, 14, 16, 20 isotopes. Similarly at N = 16 the difference between $2s_{1/2}$ - $1d_{3/2}$ is maximum. Further, in Fig.1 (b) for isotones, a large gap is noted between $1d_{5/2}$ and $2s_{1/2}$ levels and the difference is 10.53 MeV and ofcourse a large difference is found at Z = 14 in $1d_{5/2}$ - $2s_{1/2}$ and at Z = 16 at $2s_{1/2}$ - $1d_{3/2}$.

Figure 2 presents difference between the single particle energy levels $1d_{5/2}$ - $2s_{1/2}$ of isotopes and represented as a open circle, whereas the solid circle shows the difference between energy levels $2s_{1/2}$ - $1d_{3/2}$. In Fig. 2 (a) large $\triangle\varepsilon$ is noted at N = 14, 16. Similarly, in Fig.2 (b) for isotones, the differences $\triangle\varepsilon$ are shown. In Fig. 2, the point highlighted with circle shows a large difference representing the occurrence of magic numbers, whereas in isotones the differences are comparatively equal at Z = 12 and 14. This shows Z = 12 is also magic; however it needs further investigation. But a noticeable difference in SPE at Z = 16, shows the occurrence of the shell gap. From this work, it is concluded that the occurrence of the shell closure at Z, N = 14, 16 is seen through the large gap in SPE. This confirms the occurrence of new magic number at Z, N = 14, 16 in the exotic region of light nuclei.

## References


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