Thermodynamic properties of ^{130}Cd and ^{134}Te akin to ^{132}Sn

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Introduction

The solar system abundance plot of Anders and Grevess[1] reveals the distribution peaks obtained for A> 60 corresponds to neutron magic numbers which are produced by the s-process. Beyond the iron peak at A=56, the magic peak corresponding to the magic nuclei must be ^{132}Sn. According to Back et al.,[2] the nuclei $_{50}$Sn and $_{52}$Te are having the same shell orbits above Fermi surface. This enigma and the neutron magicity oriented elemental abundance in solar system induces to a comparative study of Cd, the 2-proton–hole from tin shell closure and Te, the 2-proton above Z=50, and some similarities are expected by Warr et al., [3]. It is known that Te is the most abundant element in the solar system[4] and least in the earth's lithosphere. Being a volatile element the abundance of Cd in meteorites may help better understanding of volatile-controlled processes in the solar nebula on meteorite parent bodies [5]. Recent literature on the ground state properties of even-even Cd isotopes using covariant DFT [6] revealed a shape coexistence for ^{114}Cd and a remarkable change in S_{2n}, and charge radii, at N=82. Hence N=82, the n^{o} magic number, is been fixed for the nuclei considered in this study.

Methodology

From the solar abundance study of $_{48}$Cd[5], $_{50}$Sn[7] and $_{52}$Te[3] it is ideal to describe the nuclei in a thermodynamic environment and hence, the statistical model code with temperature[8] is modified suitably and being executed in this work, treating the system hot and rotating. The spin cut-off parameter values are been obtained from our modified formula in ref[9] and ldp as a = $S^2(M,T)/4E^*(M.T)$. This work aims to describe the similarities of 2p difference neighbours to the doubly magic nucleus Z=50. Fixing the n^0 number N = 82 shell closure, the nuclei $^{130}{}_{48}$Cd, $^{132}{}_{50}$Sn and $^{134}{}_{52}$Te are been studied at different temperatures (T=0.4-2.0MeV). As a preliminary result the analysis for spin M = 0ħ only is presented in this paper.

Results and Discussion

The prolate deformed Cd nucleus at lower temperatures (γ = -120^{o}; δ = 0.1) becomes nearly spherical when the temperature is increased. A shape fluctuation (triaxial : γ = -140^{o}; δ = 0.1) is observed when the neutron number approaches its magicity, ie, spherical (δ=0.0 for ^{130}Cd).

A similar trend is also been obtained for Te nucleus but the deformation is from oblate (γ = -180^{o}) to prolate (γ = -120^{o}) and then to spherical (δ = 0.0) via triaxial (γ = -140^{o}) (δ varies to 0.2). Approaching neutron magic number, Te shows a spherical shape but Sn nucleus shows a shape change from prolate(γ = -120^{o}; δ = 0.1) to spherical via triaxial γ = -140^{o}; δ = 0.1) at lower temperatures when the neutron no is increased. Even before reaching the doubly magic nature it shows a spherical shape. (ie, at A=128, δ = 0.0). Thus the neutron magicity in the context of shape is been revealed.

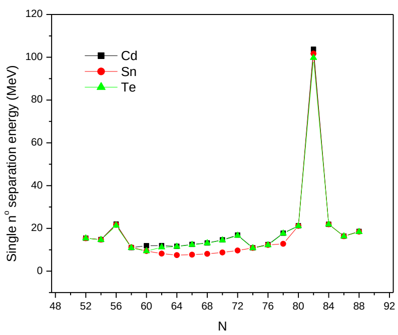

Fig. 1 Single neutron separation energy of Cd, Sn and Te isotopes at T = 0.4MeV.

The 1n^{o} separation energy of $^{130}{}_{48}$Cd, $^{132}{}_{50}$Sn and $^{134}{}_{52}$Te show a pronounced peak at

N = 82(Fig.1) which is in correlation with the experimental 1n^o separation energy of Knobel et al., [10].

Comparing the thermodynamic quantities of ^{130}Cd, ^{134}Te, and the doubly magic nucleus ^{132}Sn, reveal interesting characteristics, such as, at low temperatures (T ≤ 0.6MeV), the E* for ^{132}Sn shows low values but at T > 0.6MeV it is vice-versa (Fig.2).

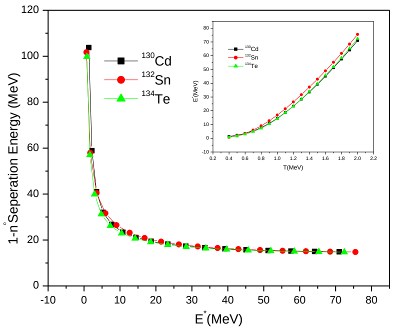

Fig. 2 Sn Vs. E* for Cd, Sn and Te with N=82; Fig insertion is E* Vs. T.

An exponential decrease of 1-n^o separation energy, with temperature or E* plotted for the Cd, Sn and Te (Fig.2) indicate their extreme sensitiveness to temperature, which gives clues of their higher existence/ abundance in the solar system.

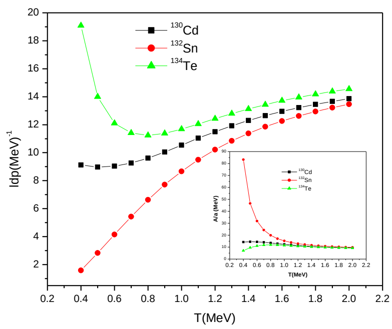

Fig. 3 ldp 'a' and 'A/a'(Fig. insertion) with temperature for Cd, Sn and Te with N=82.

The ldp against temperature (Fig.3) distinguishes the neutron magic nuclei, ^{130}Cd and ^{134}Te, from the doubly magic ^{132}Sn. At T = 0.4MeV, Δa ≈ 8MeV^{-1}(^{130}Cd) and ≈ 18MeV^{-1} (^{134}Te) to ^{132}Sn. When temperature is increased to T = 1.1MeV all these nuclei show a similar trend of becoming nearly constant. Also at this temperature (T = 1.1MeV), the coincidence of spin cut off parameter values is obtained (Fig.4).

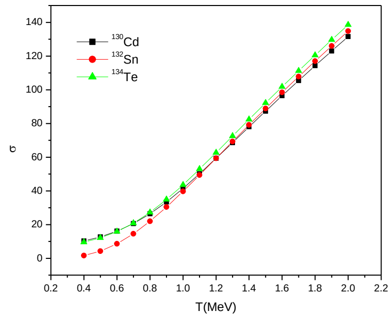

Fig. 4 Spin cut of parameter of ^{130}Cd, ^{132}Sn and ^{134}Te showing the transition temperature

Hence it is expected that at T = 1.1MeV, the transition temperature, where shell effects starts vanishing. Thus the analysis presented here reveals the similarities of nuclei with 2-proton less and above to doubly magic tin nucleus. Analysis based on varying angular momentum may yield results more relevant to astrophysical importance.

References

[1] E. Anders and N. Grevers, Geochim. Cosmochim. Acta. 53, 197 (1989).
[2] T. Back et al., Phys. Rev. C 84, 041306 (R) (2011)
[3] N. Warr et al., AIP Conf. Proc. 529, 609 (2000).
[4] E. Andres and M. Ebihara, Geochim, Cosmochim. Acta. 46, 2363 (1982).
[5] T. S. Kruijer et al., Meteorites & Planetary Science. 48, 2597 (2013) .
[6] P. Kumar and S. K. Diman, Nucl. Phys. A1001, 121935 (2020).
[7] R. D. Loss et al., Geochim. Cosmochim Acta. 53, 933 (1989).
[8] M. Rajasekaran et al., Phys. Rev. Lett. 61, 2077 (1988).
[9] S. Santhosh Kumar, Proc. Intl. Symp. Nucl. Phys. 54, 398 (2009).
[10] R. Knobel et al., Nucl. Phys. B754, 288 (2016).