Department of Physics
Central University of Tamil Nadu
Thiruvarur-610 005

Ph.D. Pre –Thesis Submission Seminar

Name of the Student : R. Madhumathy (Reg. No. R190403)
Name of the Supervisor : Dr. M. Ponmurugan
Name of the Co-Supervisor : Dr. I. Panneer Muthuselvam (BHU, Varanasi)
Title of the Thesis : **Exploring exotic ground states in alternating spin chains $Sr_2M(SeO_3)_3$, M = Co, Ni, and Cu.**
Date and Time : 28th March, 2024 at 11:00 am
Venue : Seminar Hall, First Floor, Department of Physics.

Google meet link : https://meet.google.com/yaj-htqk-dqa

Abstract

Exploring low-dimensional Heisenberg antiferromagnets offers a rich opportunity to discover exotic magnetic ground states. Lower-dimensional and gapped quantum magnets have been an important topic ever since Haldane conjecture that a 1D Heisenberg chain with integer spin harbors a gapped disordered ground state, while its half-integer counterparts are gapless. In certain spin-1/2 1D systems, frustration arising from the competition between nearest-neighboring (NN) J_1 and next-nearest-neighbor (NNN) interaction J_2 can lead to highly disordered quantum spin liquid (QSL) states devoid of long-range order (LRO). However, these spin-gap systems, characterized by a broad maximum, are susceptible to external perturbations such as anisotropy, interchain interactions, magnetic fields, and pressure, which can induce LRO. Furthermore, low-dimensional materials with low spin values (e.g., S=1/2 and 1) exhibit enhanced quantum fluctuations, giving rise to exotic ground states.

Investigating alternating spin-chain systems has garnered significant interest due to the pronounced quantum mechanical effects. This study presents experimental investigations into the structural, magnetic, and thermodynamic properties of quasi–one–dimensional alternating spin chain compounds $Sr_2M(SeO_3)_3$, where *M* = Co, Ni, and Cu. These materials crystallize in a triclinic structure with the space group $P\bar{1}$. $Sr_2Co(SeO_3)_3$ demonstrates an effective spin J_{eff} = ½ due to spin-orbit coupling. Magnetic susceptibility $\chi(T)$, magnetic specific heat $C_m(T)$, and neutron powder diffraction measurements reveal the absence of LRO down to 100 mK. Instead, a broad maximum in $\chi(T)$ and $C_m(T)$, alongside an exponential decrease of $\chi(T)$ and specific heat $C_p(T)$ as T approaches 0 K, indicates the formation of a spin-singlet ground state. Analysis based on a J_1-J_2 alternating Heisenberg model reveals a bond alternation $\alpha = J_2/J_1 \approx 0.7$ and a spin gap. Conversely, $Sr_2Ni(SeO_3)_3$, a Haldane chain material with S = 1, exhibits both short-range and long-range antiferromagnetic orders due to stronger interchain interactions compared to $Sr_2Co(SeO_3)_3$. Additionally, the temperature-field phase diagram of $Sr_2Ni(SeO_3)_3$, constructed from $\chi(T,H)$ and $C_P(T,H)$ data, shows a nonmonotonic phase boundary of T_m when an external field is applied along a hard axis. These findings suggest that the interplay of single-ion anisotropy, bond alternation, and interchain interactions influences the ground state and magnetic behavior of $Sr_2Ni(SeO_3)_3$. On the other hand, $\chi(T)$ of $Sr_2Cu(SeO_3)_3$ shows no magnetic anomaly, indicating highly quantum-disordered ground states. The substantial negative value of the Curie-Weiss temperature θ_{CW} indicates that the predominant interactions among Cu ions are antiferromagnetic. Magnetic entropy saturates at high temperatures. These findings suggest that $Sr_2Cu(SeO_3)_3$ could exhibit QSL characteristics. Our study showcases the diverse magnetic phenomena and ground states in alternating spin chain systems, resulting from the intricate interplay between spin number and metallic cations.

List of Publications

- I. P. Muthuselvam, *et.al., "Spin-singlet ground state of the coupled J_{eff}= 1/2 alternating chain system $Sr_2Co(SeO_3)_3$"*, Physical Review B**, 106,** 214417, (2022)**.**
- R. Madhumathy, *et.al., "Crystal growth and magnetic properties of the coupled alternating S = 1 spin chain $Sr_2Ni(SeO_3)_3$"*, Physical Review B, **107,** 214406 (2023).
- R. Madhumathy, *et.al.*, "*A possible Quantum Spin liquid state in $Sr_2Cu(SeO_3)_3$.*, "*A possible Quantum Spin liquid state in $Sr_2Cu(SeO_3)_3$. (Under review).*