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Ph.D. Evaluation Committee
Department of Theoretical Physics
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Report Dissertation Zhirayr Adamyan

18. May 2025

Dear colleagues,

Following your request, I would like to submit my report on the Ph.D. thesis "Some problems of low dimensional quantum magnetism" by Mr. Zhirayr Adamyan.

Yours sincerely,

Prof. Dr. Jürgen Schnack

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Report on the dissertation

Some problems of low dimensional quantum magnetism

by Zhirayr Adamyan

The thesis "Some problems of low-dimensional quantum magnetism" is presented by Zhirayr Adamyan for the degree of a Candidate of Physical and Mathematical Sciences in Specialization **01.04.02-Theoretical Physics**.

Overview

The thesis of Zhirayr Adamyan deals with theoretical investigations of the quantum properties of small magnetic systems of two or three spins in view of their entanglement properties. This research is motivated by and important for future quantum technologies. The submitted thesis goes far beyond typical studies that investigate rather homogeneous spins systems whereas here spin systems are studied where the total magnetization is not a good quantum number. A non-conserved total magnetization or its z-component would allow to drive the system in a non-trivial way by means of a homogeneous external magnetic field. Magnetic clusters with such properties exist as magnetic molecules, and the candidate provides valuable examples thereof. The identification and discussion of distinct entanglement regimes made in the thesis and their control is of utmost importance for future applications. In this respect, the thesis provides a valuable advancement in view of future spin-based quantum technology.

Structure and Content

In the **Introduction** Mr. Adamyan introduces the reader to the field of molecular magnetism and sets the stage for his later investigations by defining and explaining core concepts such as entanglement and decoherence. He also introduces the spin models employed in this thesis and discusses in particular the role of the g-factor. For the spin dimers and trimers used later in the thesis he defines bipartite and tripartite entanglement and refinements of the later, compare, e.g., entanglement types in Fig. 1. Entanglement measures such as concurrence and negativity are introduced.

Chapter 1 discusses two different spin systems. Here dimers of two spins ½ are considered as well as mixed-spin dimers with one spin ½ and one spin 1. The candidate explores both systems as function of varying magnetic fields, anisotropy parameters, and g-factors. Concurrence and negativity in both ferromagnetically as well as antiferromagnetically coupled dimers are evaluated and discussed. For certain scenarios as for instance appropriate differences in g-factors and certain magnetic field strengths the entanglement can be enhanced or even maximized.

Chapter 2 is devoted to a triangular mixed spin-(1/2,1/2,1) trimer, again with non-uniform Landé g-factors. Since the system is small enough the Hamiltonian can be diagonalized analytically; therefore eigenvalues, eigenstates, and entanglement measures can be evaluated. The candidate presents ground state phase diagrams and discusses the entanglement structure. As explained in the introduction the candidate looks for the distinct entanglement regimes (fully separable, biseparable, and tripartite entangled) which can indeed be identified in this system. As I already wrote in the overview, the exciting advancement of these systems compared to isotropic systems is that they can be tuned by homogeneous external magnetic fields which are much more easily produced than inhomogeneous fields in particular in view of the molecular length scales. This means that magnetic molecules with non-conserved magnetization provide a much more promising tool to achieve a simple manipulation of quantum entanglement by means of homogeneous magnetic fields.

In **Chapter 3** Mr. Adamyan models a magnetic molecule containing a linear trimer of Cu^{2+}-, Ni^{2+}-, and C^{2+}-ions. Again, bipartite and tripartite entanglement as well as quantum coherence are evaluated using analytical and numerical methods both as function of applied magnetic field as well as temperature. The molecule appears promising according to the discussion of Mr. Adamyan since its entanglement measures remain rather intact up to astonishingly high temperatures and very large magnetic fields.

In his **Summary** the candidate very nicely recapitulates the ideas and results of his investigations. This is followed by a **Bibliography** that contains the relevant literature and thus shows that the candidate is familiar with the field.

Evaluation

Summarizing the above, I can conclude that the thesis provides a sufficiently comprehensive study; it offers new and important insights into entanglement features of small quantum spin systems. Therefore, I can state, that Mr. Zhirayr Adamyan shows familiarity with and understanding of the topic.

Despite of the high quality of the thesis, it is nevertheless not without shortcomings. Particularly, I would like to mention the following points:

1. The candidate uses the term "transition" at crossings of levels in the Zeeman diagram. Personally, I find this terminology not strict enough. For pure states it matters whether two levels cross or anti-cross. Only in the latter case we observe (Landau-Zener-Stückelberg) transitions. The transitions Mr. Adamyan speaks of are (T=0)-equilibrium transitions.

2. The candidate discusses negative g-factors. Here I would have liked some remarks in his thesis on whether and how this is possible. One option from my point of view would be a coupled system of an electronic spin system and a nuclear system that could have opposite signs of g.

However, these minor flaws do not affect the quality and the values of the thesis.

Summary

The methods and techniques applied are appropriate to the subject matter. The thesis satisfies the requirements of the Higher Education and Science Committee of the Republic of Armenia for theses seeking the degree of Candidate of Physical and Mathematical Sciences.

Based on the above, I conclude that Zhirayr Adamyan deserves to be awarded the degree of Candidate of Physical and Mathematical Sciences in the specialization 01.04.02 - "Theoretical Physics". The abstract completely reflects the content of the thesis.

Bielefeld, den 18. May 2025

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