IOPscience iopscience.iop.org

Home Search Collections Journals About Contact us My IOPscience

Reply to Comment on 'Quantum entanglement and neutron scattering experiments'

This article has been downloaded from IOPscience. Please scroll down to see the full text article.

2004 J. Phys.: Condens. Matter 16 5635

(http://iopscience.iop.org/0953-8984/16/30/N02)

View the table of contents for this issue, or go to the journal homepage for more

Download details:
IP Address: 129.252.86.83
The article was downloaded on 27/05/2010 at 16:15

Please note that terms and conditions apply.

INSTITUTE OF PHYSICS PUBLISHING JOURNAL OF PHYSICS: CONDENSED MATTER

J. Phys.: Condens. Matter **16** (2004) 5635–5636 PII: S0953-8984(04)77797-8

REPLY

Reply to Comment on 'Quantum entanglement and neutron scattering experiments'

R A Cowley[1]

Department of Astronomy and Physics, Canterbury University, Private Bag 4800, Christchurch 8020, New Zealand

Received 17 March 2004
Published 16 July 2004
Online at stacks.iop.org/JPhysCM/16/5635
doi:10.1088/0953-8984/16/30/N02

Abstract

Karlsson and Lovesey's explanation of the intensity loss in EVS experiments on H as a consequence of quantum entanglement is flawed as, in particular, their results do not satisfy the first moment sum rule. The reason for the loss of intensity is probably either the failure of the Born–Oppenheimer approximation or experimental error.

There has been considerable interest and controversy caused by the reports of quantum entanglement in hydrogen containing systems, made with experiments performed with very high energy neutron scattering using the EVS spectrometer at ISIS. In addition, theoretical papers by Karlsson and Lovesey [1] have supported these results by developing a theory which suggested that a lack of intensity in the scattering could result from quantum entanglement.

I consider that their development is flawed and in my earlier paper [2] presented a number of reasons for this. Unfortunately Karlsson and Lovesey [3] in their comment do not answer any of the specific points raised in that paper and only state that they do not believe the conclusions that I drew from analysis of a simple spin model. I consider that my use of a simple magnetic model is justified and does not complicate the argument unnecessarily. The impulse approximation makes the scattering largely incoherent while there is a sum over all spin states for the hydrogen atom. Ignoring these complications enables the essential physics to be understood more easily.

I now repeat more briefly the comments made before. In the first of their papers, the orthogonality condition is invoked to eliminate the transitions from a state J to J. This leads to the scattering depending solely on the incoherent cross-section which is inconsistent with the scattering observed from the highly entangled superfluid ^{4}He. This error was corrected in a later paper [4] but the development still depends on the assumptions made about the detailed nature of final state wavefunction. I consider that there are alternative assumptions that do not

[1] Permanent address: Department of Physics, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, UK.

 © 2004 IOP Publishing Ltd Printed in the UK

give any change from the conventional arguments. I do not understand the particular relevance of Mott scattering because the scattered neutron is not one of the sample particles.

Because of the difficulty and complexity of deciding on the correctness or otherwise of the final state wavefunction, I suggested an alternative argument based on the first-moment sum rule which Karlsson and Lovesey [3] agree is satisfied by the system. The main point was that the first-moment or f-sum rule for the scattering does not depend on the inter-atomic forces and whether they are dipolar or exchange in nature and neither does it depend on the form of the quantum mechanical ground state and whether the particles are entangled or not entangled. It does depend on any velocity dependent forces but these are assumed to be negligible.

It is well known that it is very difficult to test moment relations with neutron scattering techniques and one of the points made by Karlsson and Lovesey [3] is that they have not attempted a full calculation of $S(Q, \omega)$. In their comment they mention the possibility of high energy scattering not included in the Born–Oppenheimer approximation or scattering at lower energies from lattice vibrations or defects. These are indeed possible but they are completely new and different mechanisms from entanglement and have been suggested, for example, by Reiter and Platzman [5]. I consider that these mechanisms may provide an explanation for the effects observed.

I am not convinced, however, that these provide a convincing explanation of the experimental data. Reiter and Platzman [5] point out that the integral of $S(Q, \omega)$ is one. It is then necessary to modify the scattering function to reduce the intensity at the impulse approximation energy while preserving the zero and first moments. This requires the additional intensity to be distributed at both higher and lower energies than the impulse approximation. A more likely experimental scenario is that there are excited electronic states at higher energy in which case the bulk of the impulse approximation peak occurs at lower energy, as found experimentally in impulse experiments [6] on solid N_2 due to the molecular binding in the system. If this is the case then the good agreement of the hydrogen positions with simple theory makes the interaction with electronic degrees of freedom an unlikely explanation. I can agree with Karlsson and Lovesey [3] that further work is needed to clarify the relation between the different models and to understand these interesting results.

Acknowledgment

I have benefited in preparing this reply from helpful discussions with George Reiter for which I am grateful.

References

[1] Karlsson E B and Lovesey S W 2000 *Phys. Rev.* A **61** 062714
[2] Cowley R A 2003 *J. Phys.: Condens. Matter* **15** 4143
[3] Karlsson E B and Lovesey S W 2004 *J. Phys.: Condens. Matter* **16** 5631
[4] Karlsson E B and Lovesey S W 2002 *Phys. Scr.* **65** 112
[5] Reiter G F and Platzman P M 2004 at press
[6] Zinkin M P, Cowley R A, Eccleston R S, Evans A C and Harris M J 1995 *Can. J. Phys.* **73** 772