Spin state of Mn_3O_4 investigated by ^{55}Mn nuclear magnetic resonance

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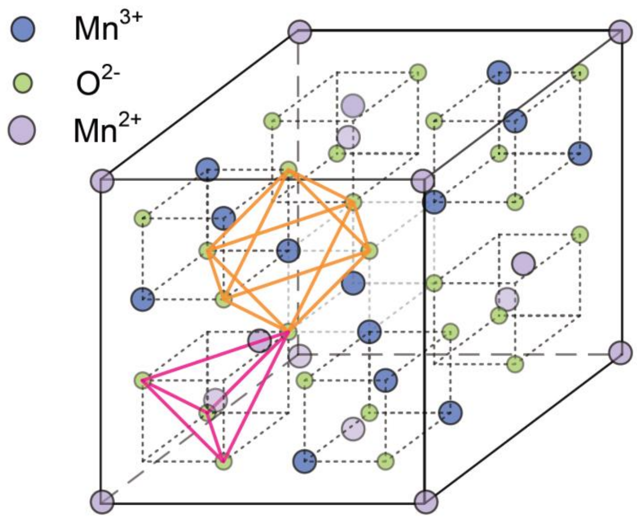
Outline

- Structural and magnetic properties of the spinel oxide Mn_3O_4
- Nuclear magnetic resonance experiments for the magnetic materials
- Spin state of Mn_3O_4 investigated by NMR

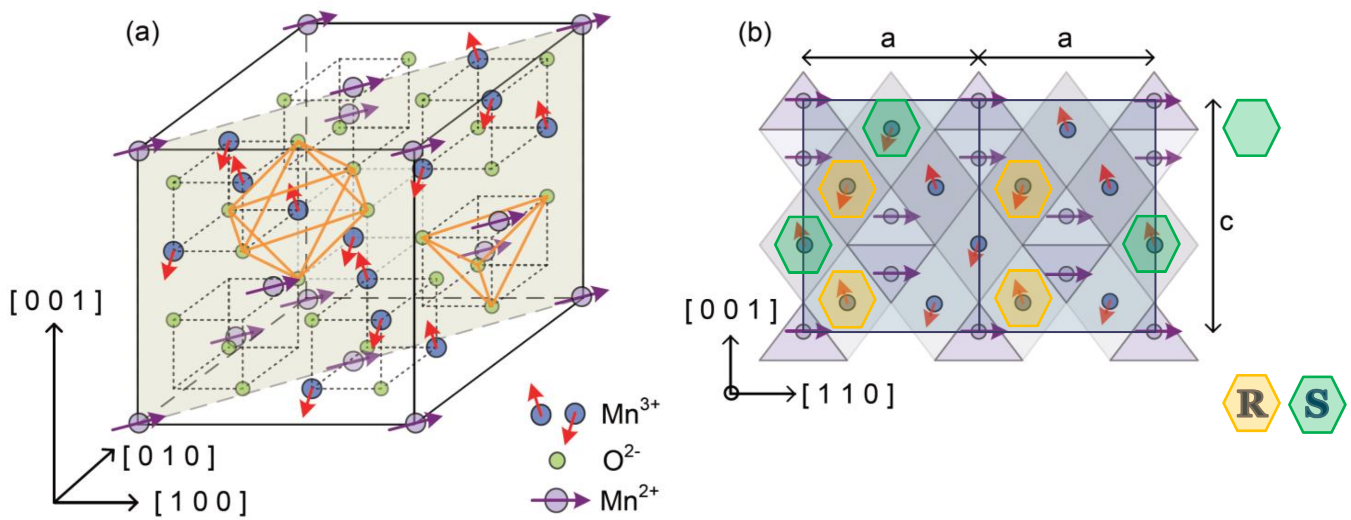
Properties of the spinel oxide Mn_3O_4

- AB_2O_4 spinel structure
- Mn^{2+} ($3d^5$) ion in the A(tetrahedral) site
- Mn^{3+} ($3d^4$) ion in the B(octahedral) site
- Phase transition



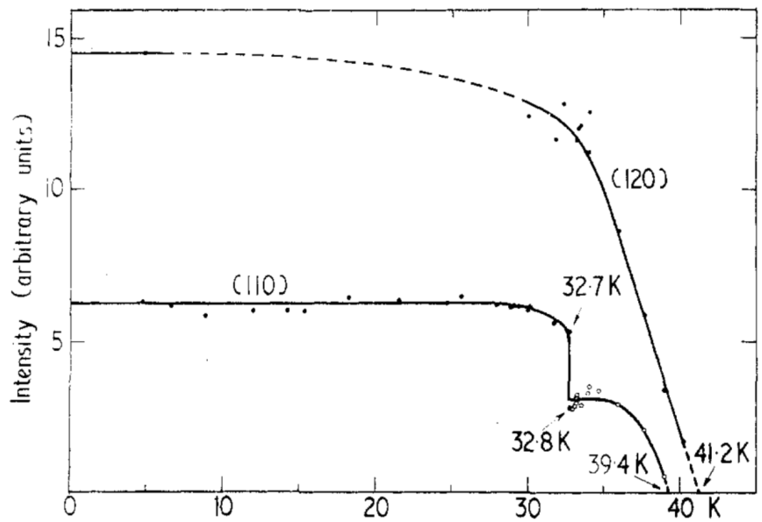
Structural	monoclinic	tetragonal			cubic
Magnetic phase	Cell doubled phase(ferri-)	Incommensurate conical phase	Yafet-Kittel(ferri-)	Paramagnetic phase	
	33K	39K	43K	1443K	

Cell doubled phase



- Commensurate ferrimagnetic ordering in which the net magnetic moment is along the [110] direction
- The magnetic unit cell doubles the chemical unit cell

Commensurate-Incommensurate phase transition



[J. Phys. C. (1974) G. B. Jensen and O. V. Nielsen]

- Different temperature dependence of neutron intensity for (120) reflection related to the R spin and (110) reflection related to the S spin
- Only S spin(cell doubling spin) is related to the Commensurate-Incommensurate phase transition

Different magnetic moment R and S

- According to the B. Boucher, R. Buhl and M. Perrin's neutron diffraction experiment results, the magnetic moment R and S have the same magnitude but different canting angles

[B. Boucher, R. Buhl, and M. Perrin, J. Appl. Phys. **42**, 1615 (1971)]

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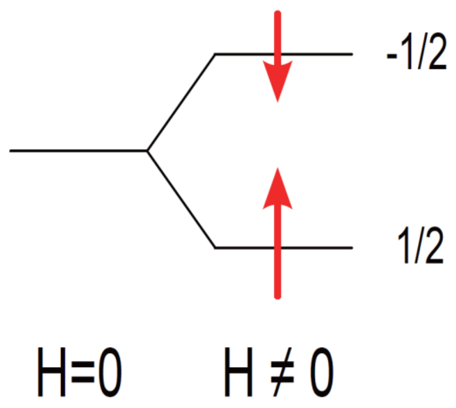
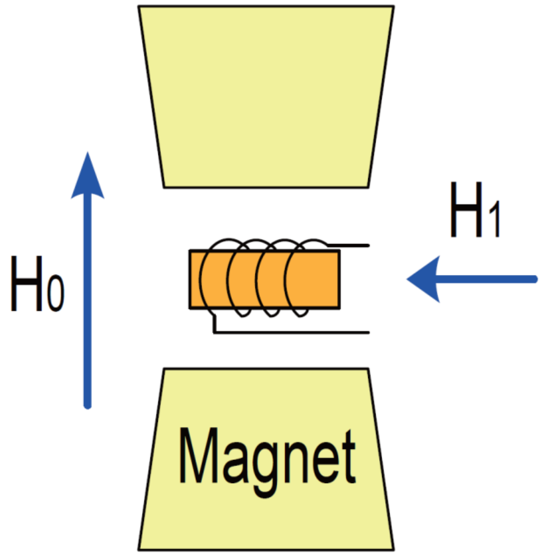
[G. B. Jensen and O. V. Nielsen, J. Phys. C **7**, 409 (1974)]

NMR (nuclear magnetic resonance)

- Good technique to investigate magnetic properties as a local probe





$$\omega = \gamma H$$

Zero field NMR

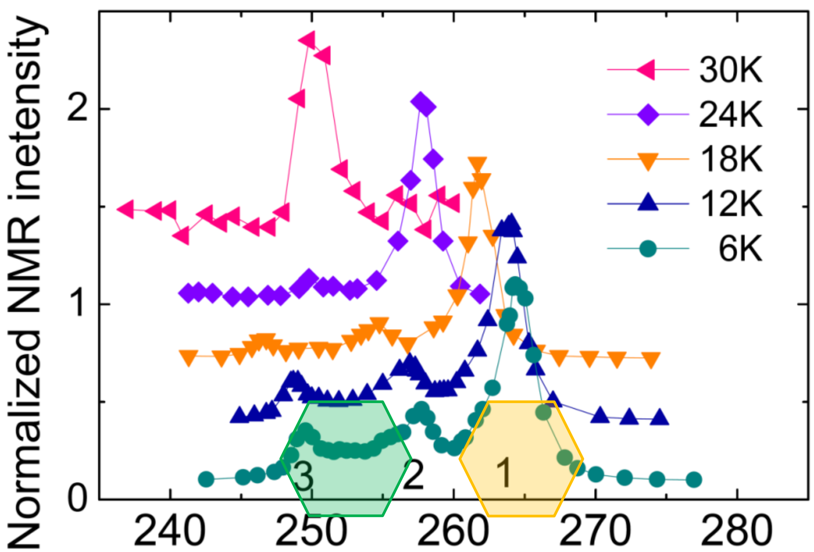
- In general:
  $\omega = \gamma H \rightarrow \omega = \gamma(H_{hyp} + H_{ext})$

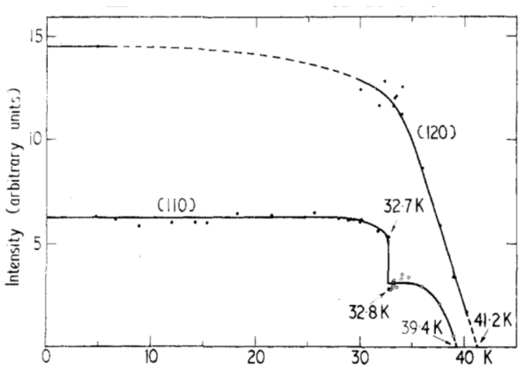
- In absence of the external magnetic field :
  $\omega = \gamma H_{hyp}$

- In the magnetic material :
  $\boldsymbol{\omega} = \boldsymbol{\gamma A \mu}$, (A = hyperfine field constant, μ = magnetic moment)

- Resonance frequency is proportional to the magnetic moment !!

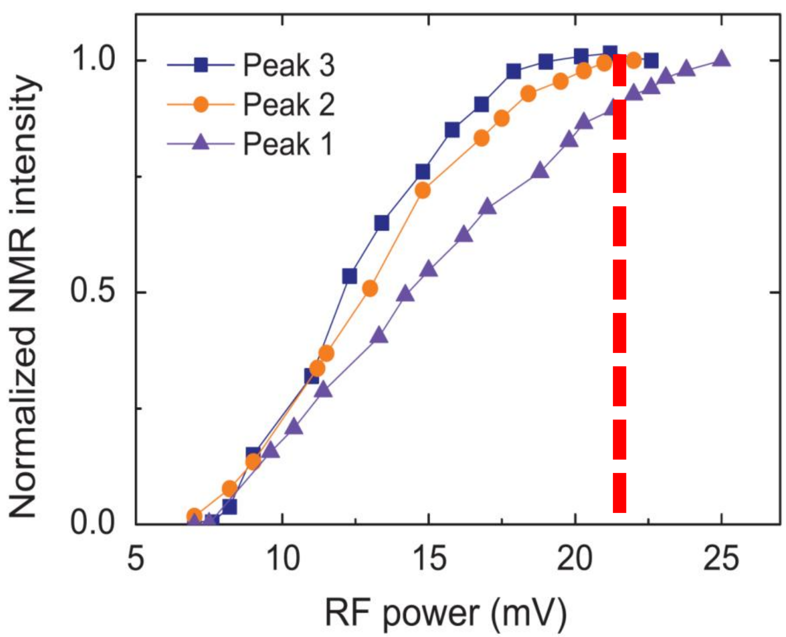
Temperature dependence of the NMR spectrum





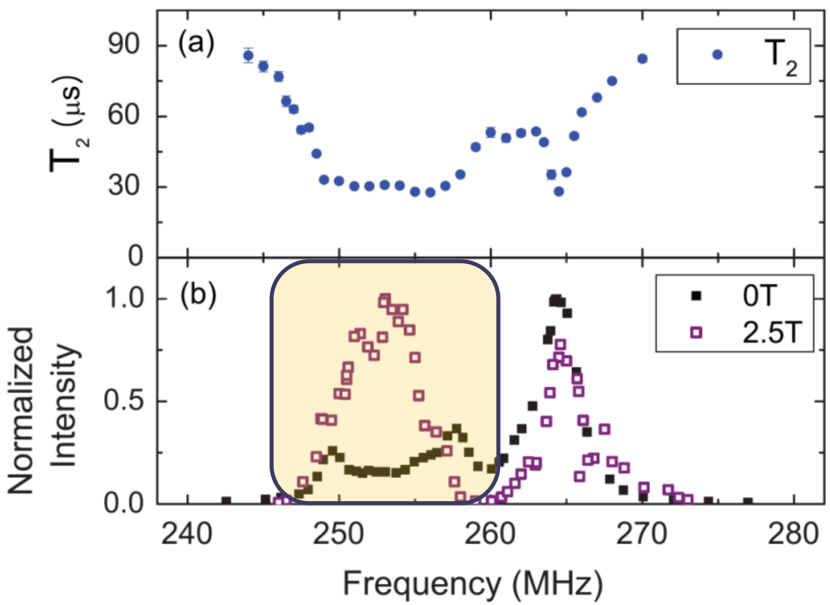
- Zero field NMR spectrum for Mn^{3+} ion in Mn_3O_4 consists of 3 peaks
- The temperature dependence of the each peak is different
- The peak1 comes from R spin and peaks 2 and 3 come from S spin which is related with commensurate-incommensurate phase transition

RF power dependence of peak1,2 and 3



- Different rf power dependence of the normalized nmr intensity at each peak position
- rf enhancement created by oscillating electron spin depends on the anisotropy field
- Magnetic moment related to the peak 1 is in the different environment from that of peak 2 and 3

Suhl-Nakamura interaction in Mn_3O_4



- Frequency dependence of the Spin – spin (T2) relaxation time
- Central parts of the peaks 2 and 3 in the spectrum measured in 0T magnetic field is suppressed
- The fast relaxation at the peak position due to the Suhl-Nakamura interaction
- Spin – spin relaxation due to Suhl-Nakamura interaction gets slower with external magnetic field
- Suhl-Nakamura interaction broadens the peak related to the magnetic moment S

Conclusions

- The temperature dependence of the NMR spectrum and the rf enhancement factor show that Mn^{3+} ions have two different states of magnetic moment, one of which is strongly related to the commensurate-incommensurate phase transition

- The Suhl-Nakamura interaction is the one of the main relaxation mechanism