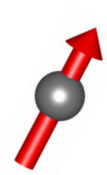
Atomic magnetism

Hund's rules, Van Vleck paramagnetism

x-ray spectroscopy: XAS and XMCD

Friedrich Hund and John Van Vleck



by Alexander Tsirlin, Leipzig University

Lecture 3: November 4, 2024

Magneton

← **Magnetilo** Pokémon-Liste • Anime-Auftritte • Sammelkarten

Magneton ist ein Pokémon mit den Typen Elektro und Stahl und exi[illegible] seit d[illegible] Spielg[illegible] Vor Veröffentlichung der zweiten Spielgeneration besaß es ausschließli[illegible]yp Ele[illegible]

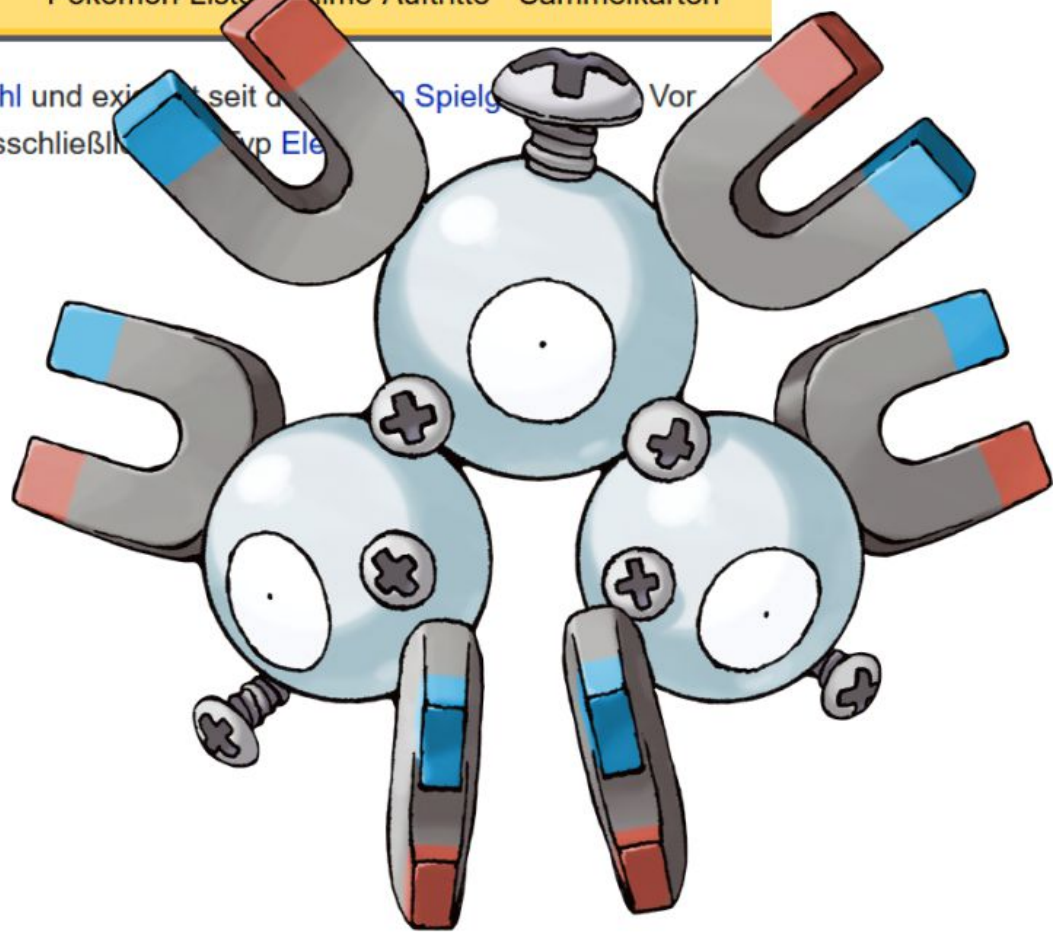
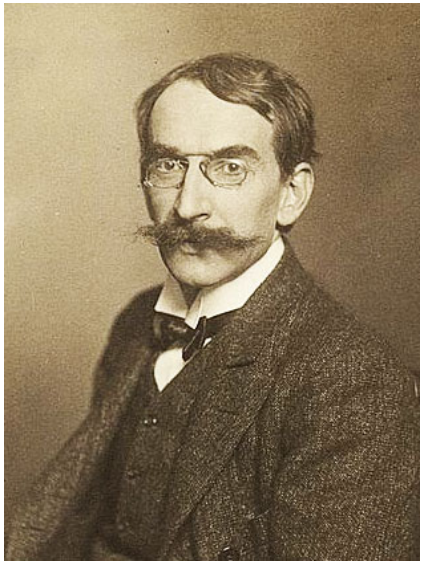
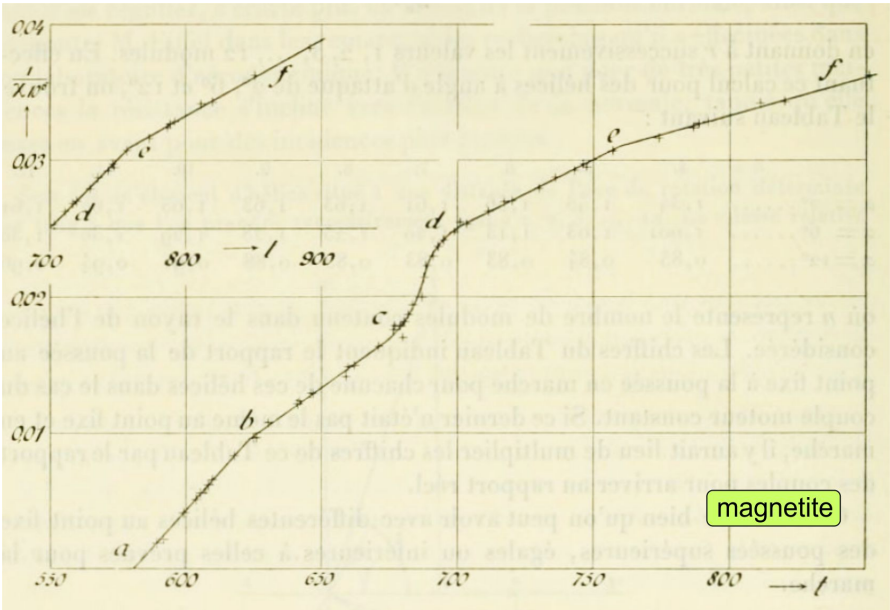


Image credit: pokewiki.de (fair use)

Pierre Weiss (1865–1940)





M_s of Ni and Fe: the 3:11 ratio

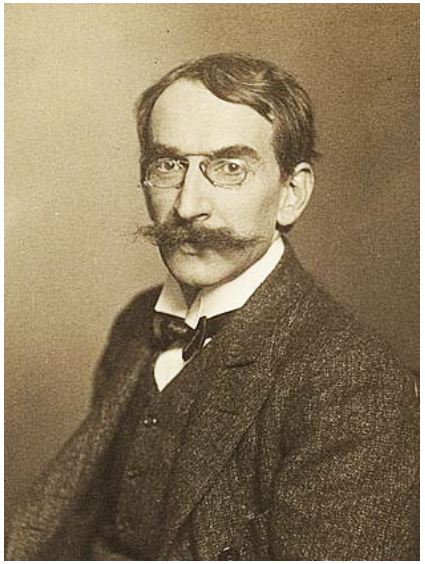
linear regions in $1/\chi$ (magnetite)

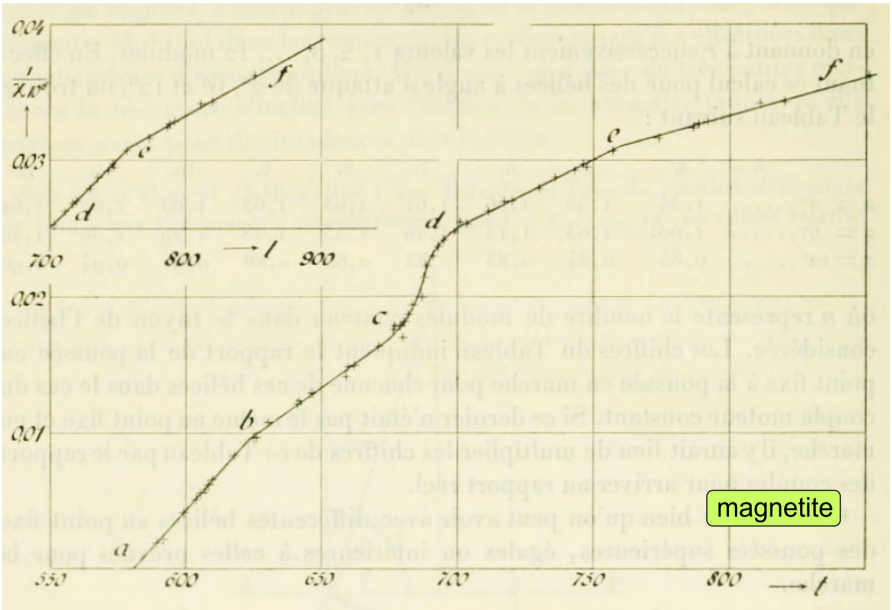
Weiss magneton:

1.85×10^{-24} J/T $\simeq 0.2\,\mu_B$

Pierre Weiss (1865–1940)

I have no qualms in substituting for the phrase
"sample that does not follow the theory",
the phrase, "sample that does not keep the same number of magnetons throughout the interval under study" (1911)





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1885–1962

1911: Bohr-van Leeuwen theorem

no magnetism in classical mechanics

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published only in Danish

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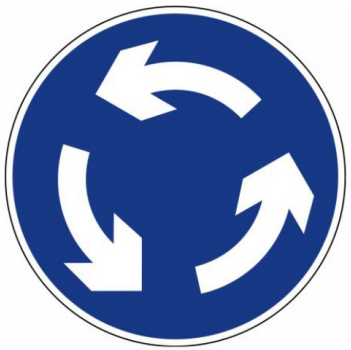
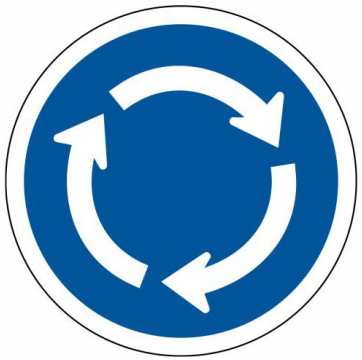
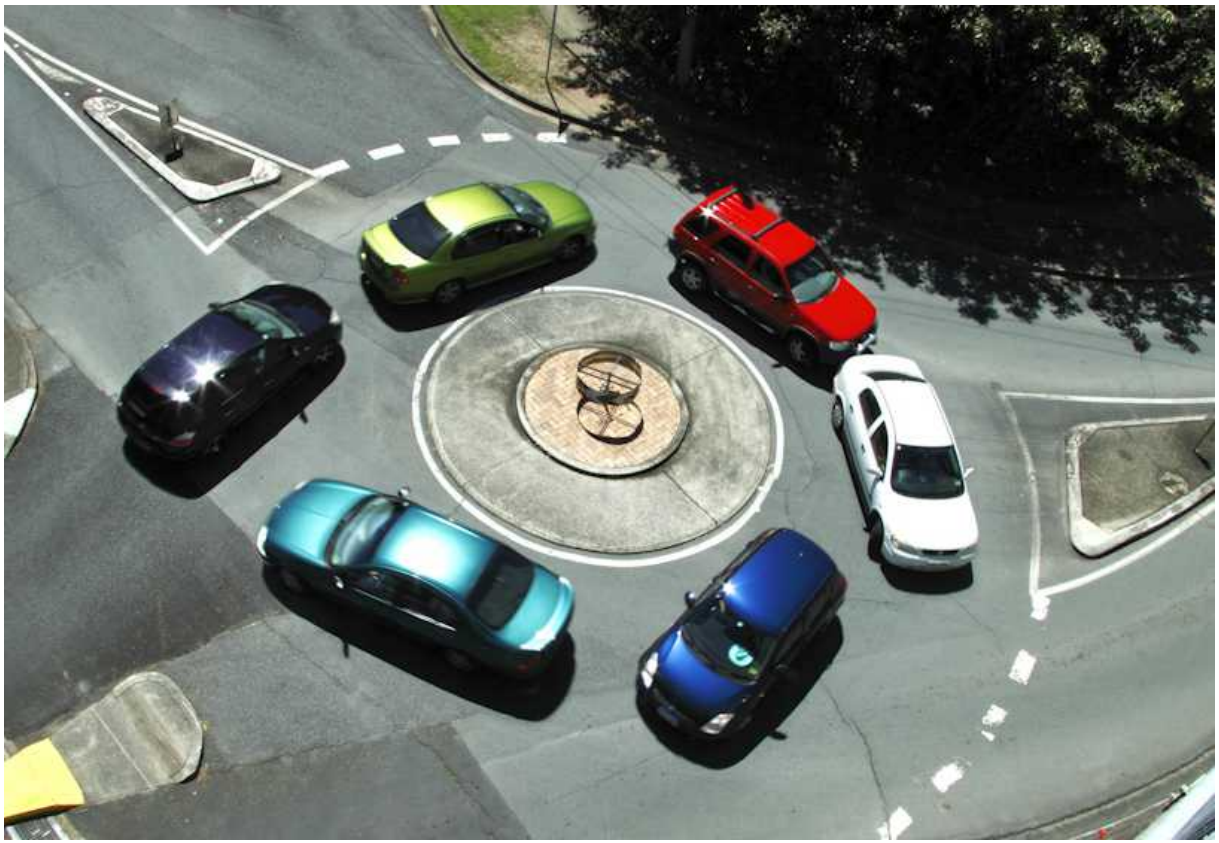
1920: Bohr magneton
introduced by Wolfgang Pauli,

antagonistic to the Weiss magneton of the experimentalists

Second Hund's rule (of a roundabout)







All should move in the same direction!

Image credit: Marty Portier (CC-BY-SA), mikedelgrosso.co.uk (fair use)

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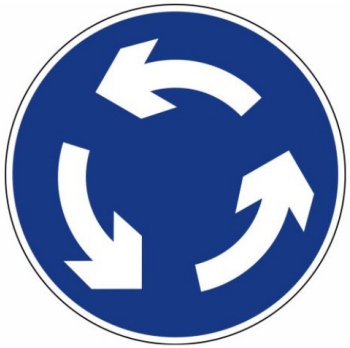

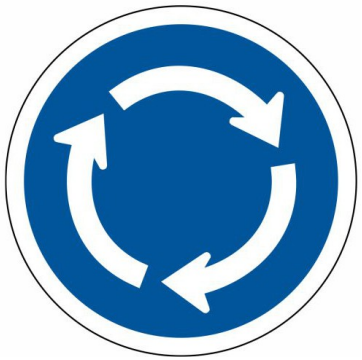

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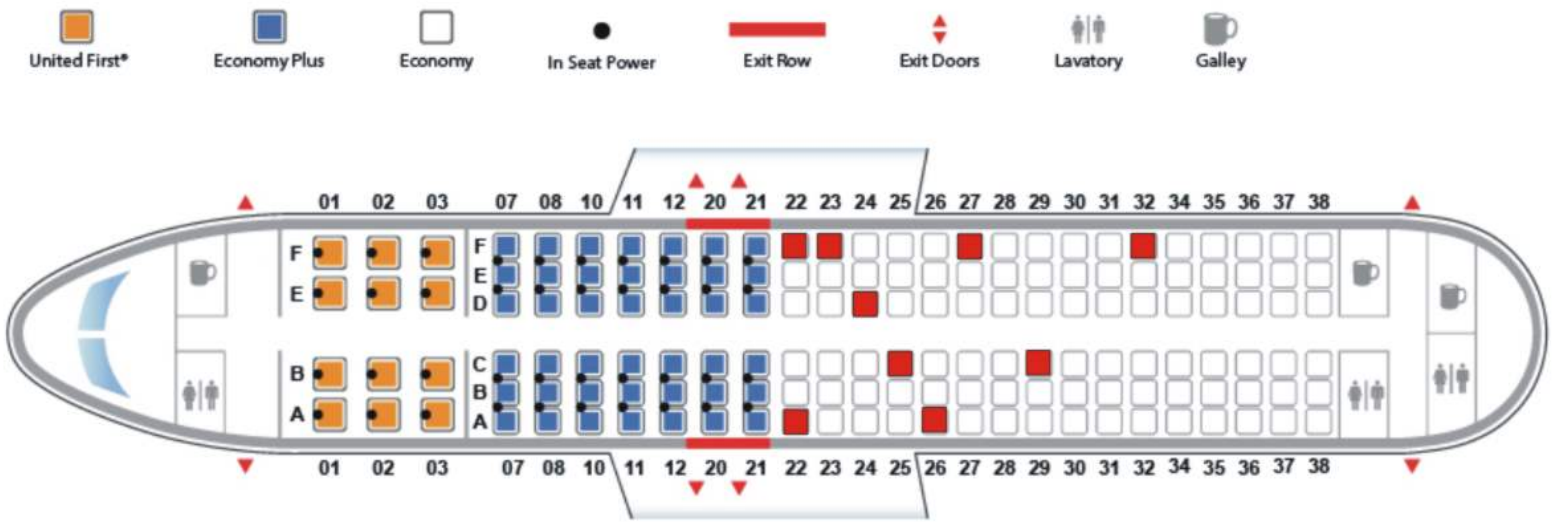
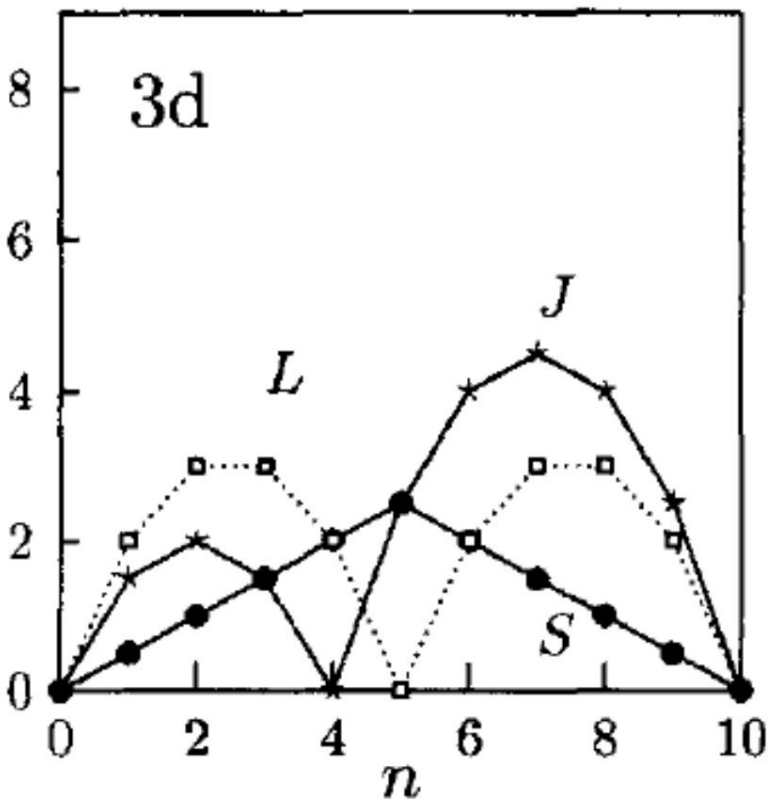


First Hund's rule: empty rows preferred

Second Hund's rule: front rows preferred (more legroom)

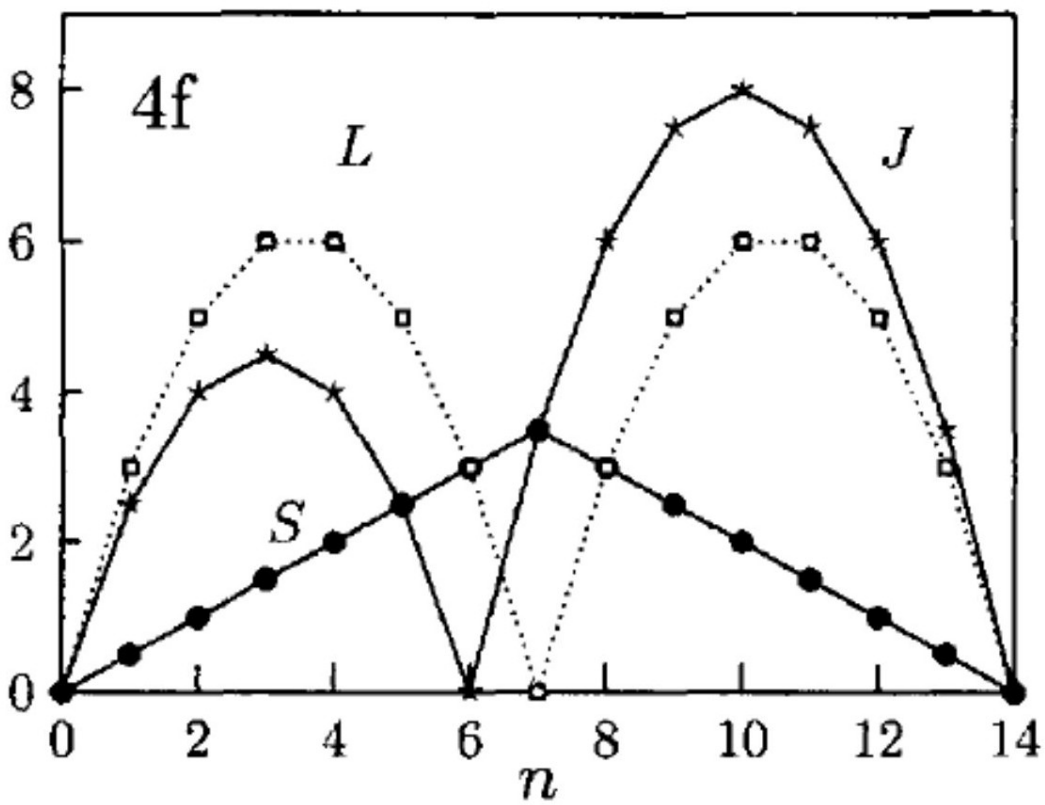
Third Hund's rule: left or right side preferred, depending on the flight direction



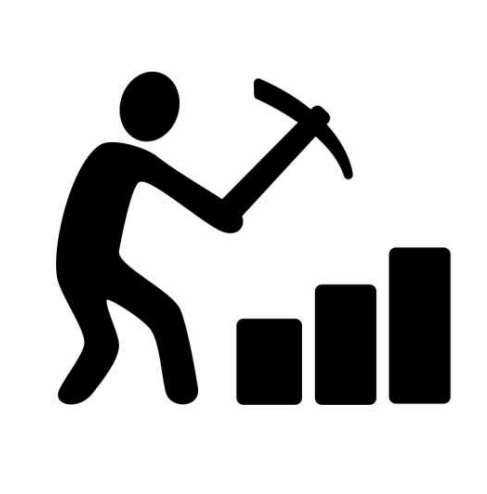
1) S maximized

2) L maximized

3) $J = L - S$ (below half-filling)
$J = L + S$ (above half-filling)

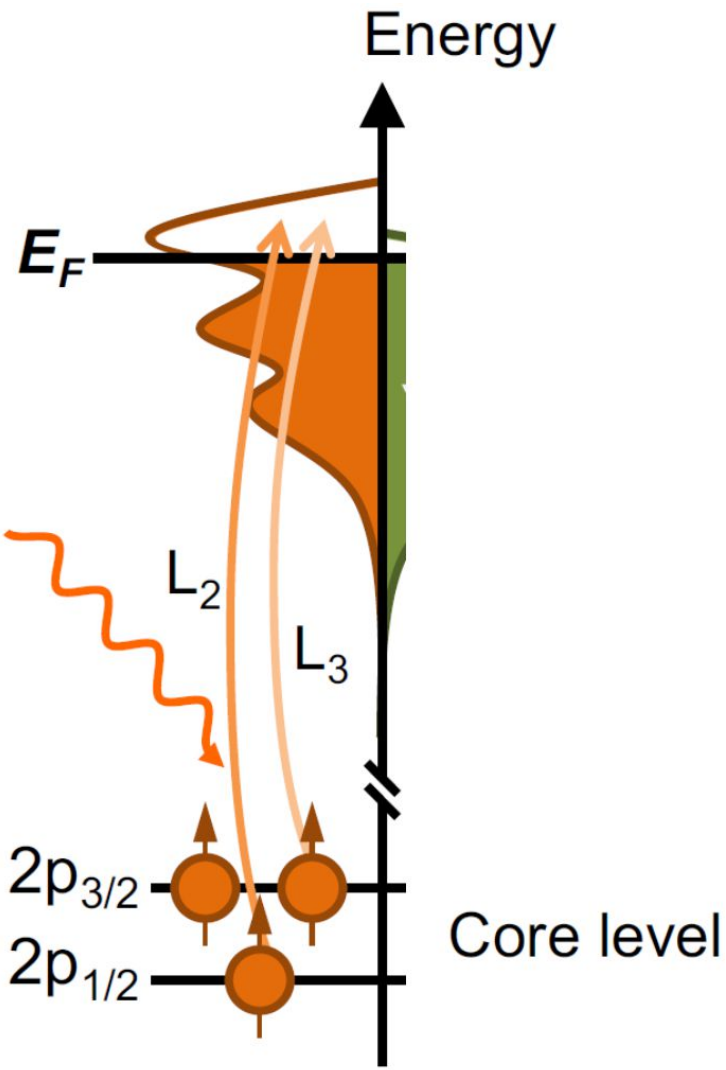


S. Blundell, Magnetism in Condensed Matter

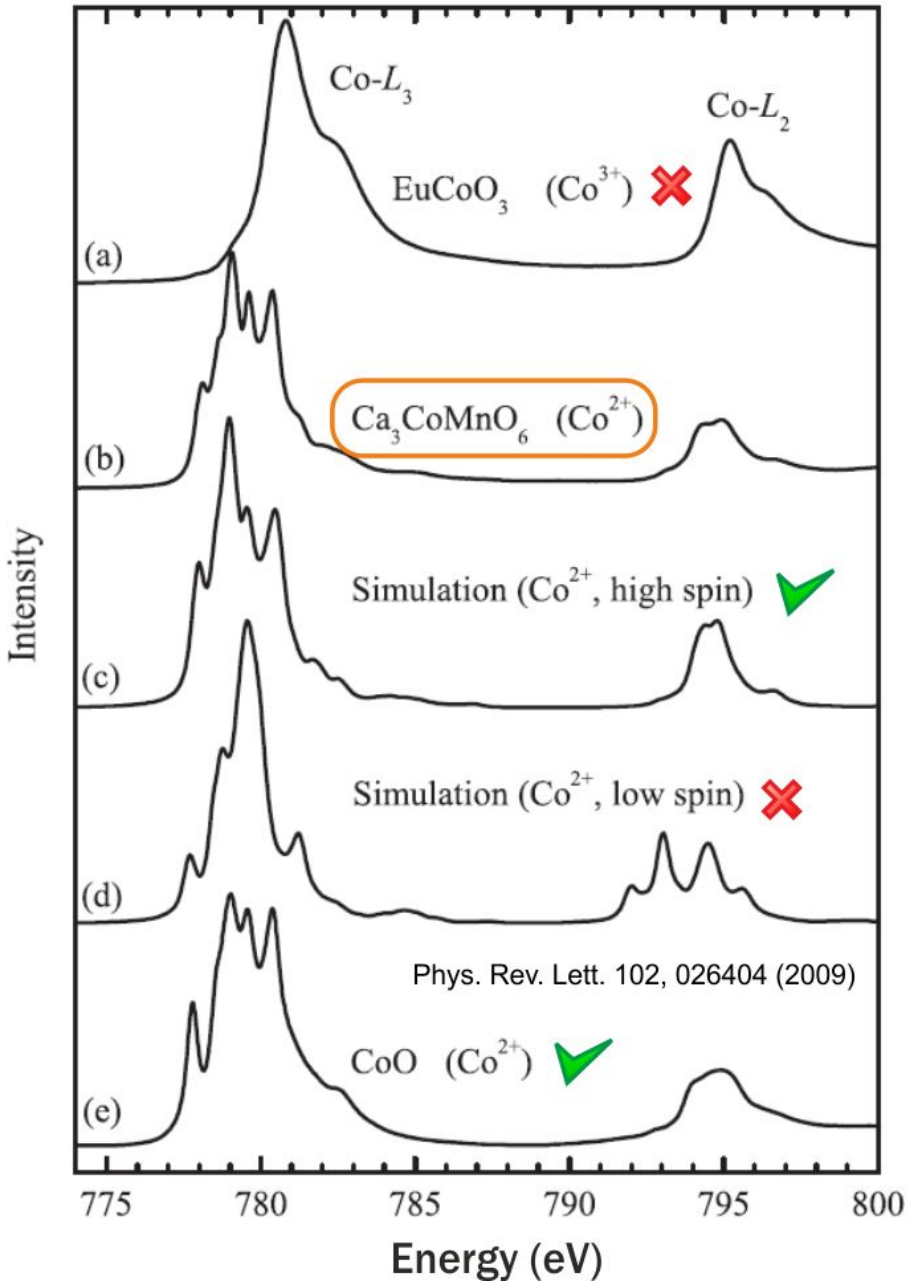


Experiment

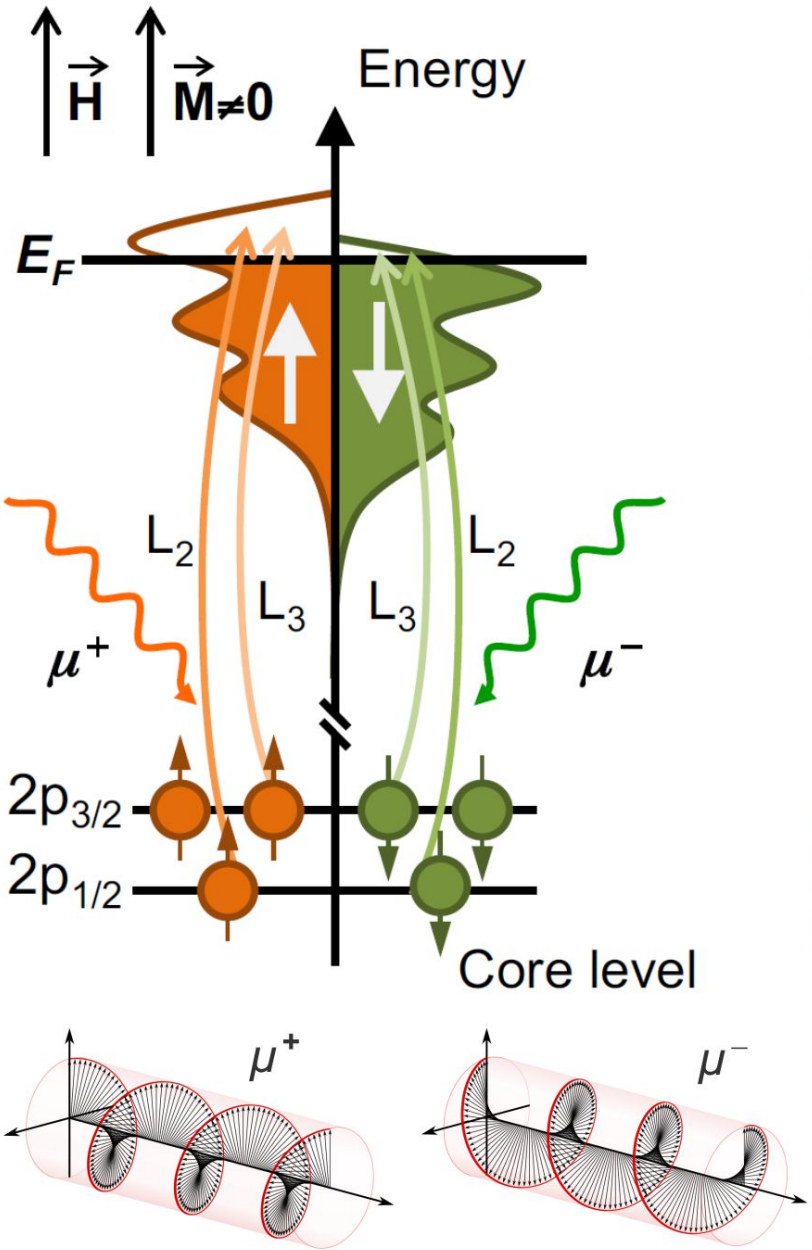
x-ray spectroscopy: XAS and XMCD

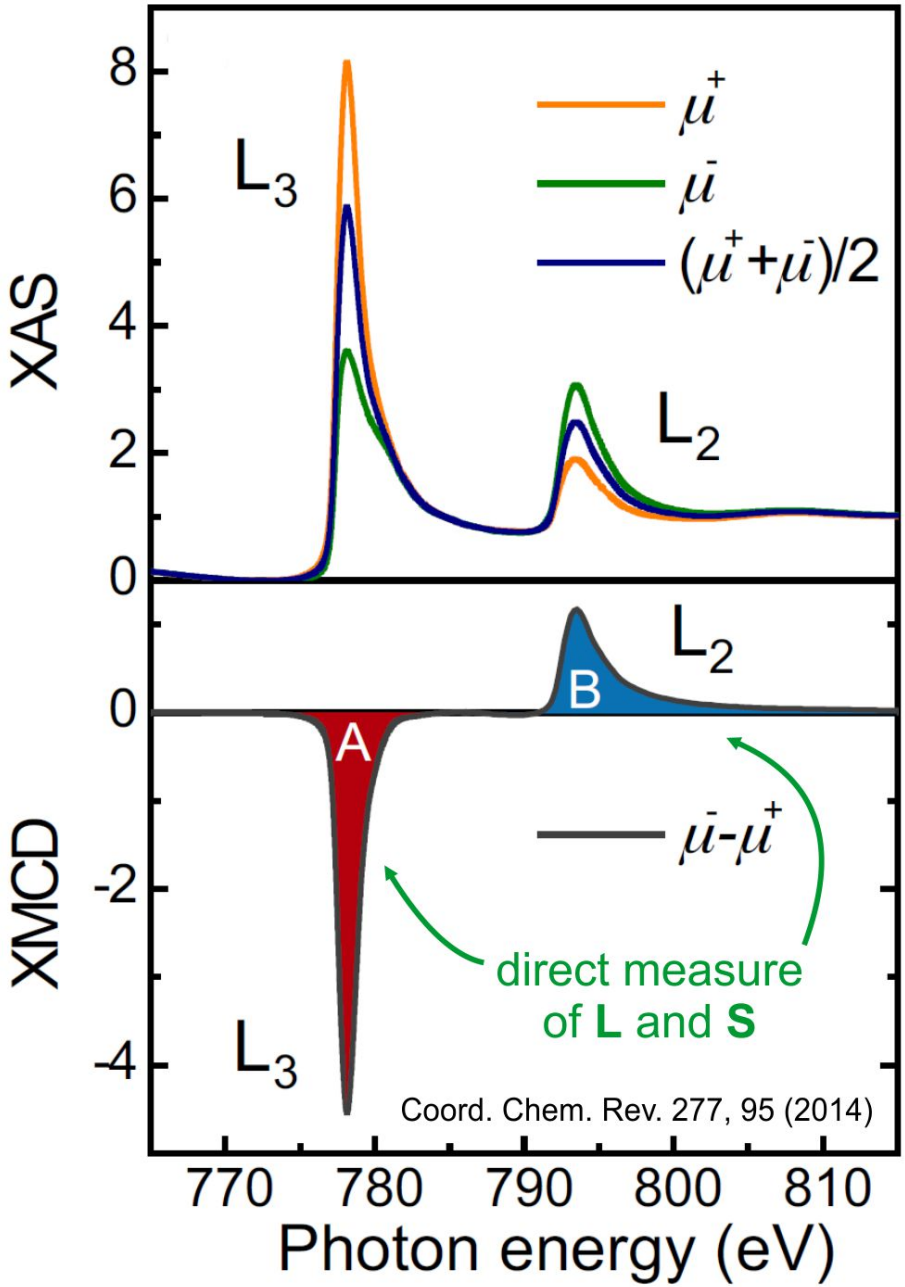


Coord. Chem. Rev. 277, 95 (2014)



X-ray magnetic circular dichroism

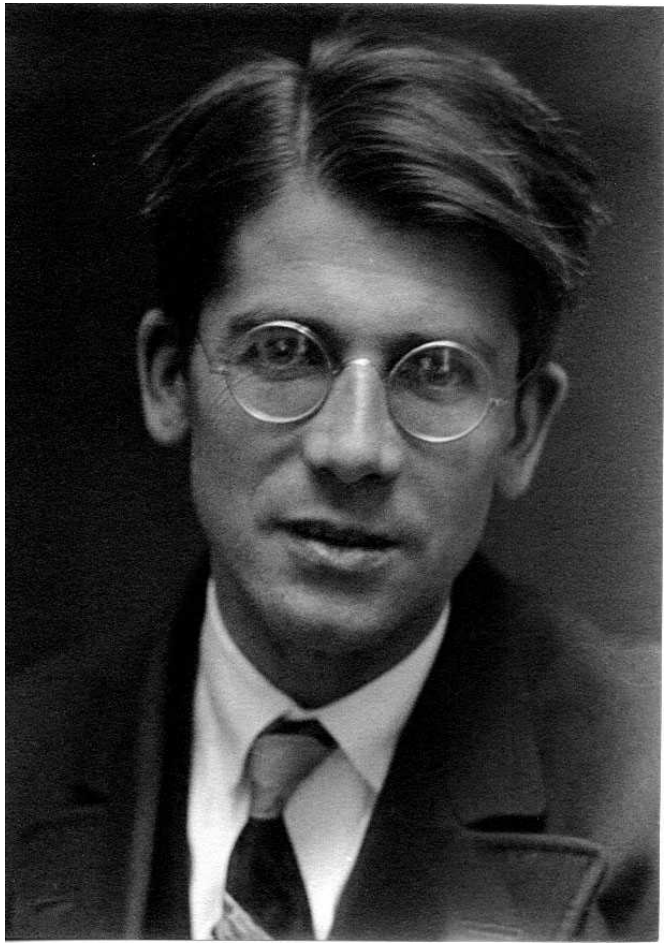




Person

Friedrich Hund

John Van Vleck



Friedrich Hund
1896–1997

- 1915-22: study in Marburg and Göttingen
- 1922-27: Born's assistant in Göttingen
- 1925: **Hund's rules**
- 1927: theory of **molecular orbitals** (*Hund-Mulliken theory*)
- 1927-29: professor in Rostock
- 1929-46: professor in Leipzig, seminar *Heisenberg mit Hund*
- 1945: refuses to leave to the West, describes the exodus as "deportation into slavery" and "professors moved around like machine parts"
- 1946-51: professor in Jena
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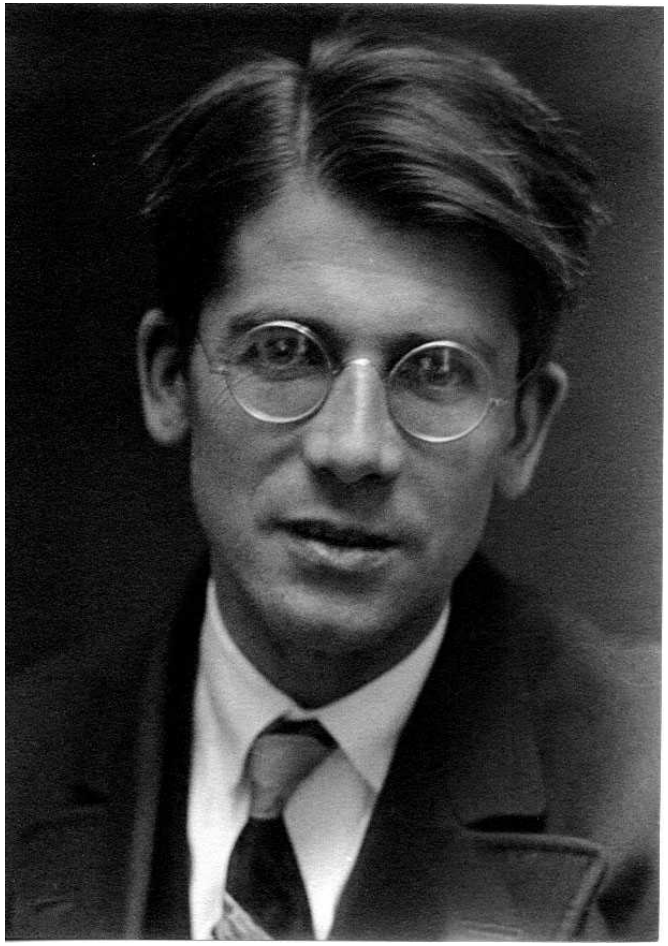

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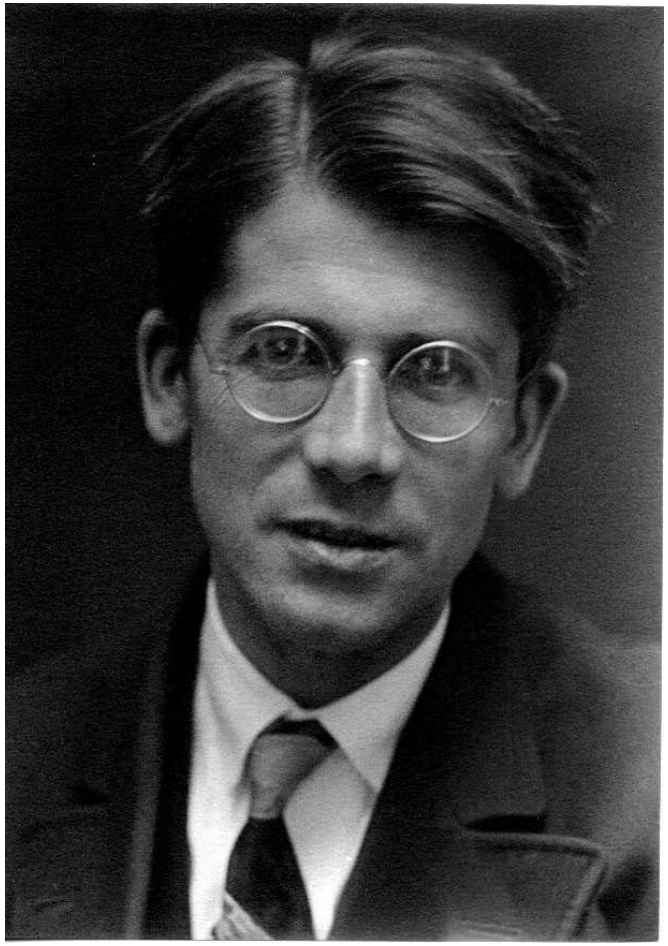

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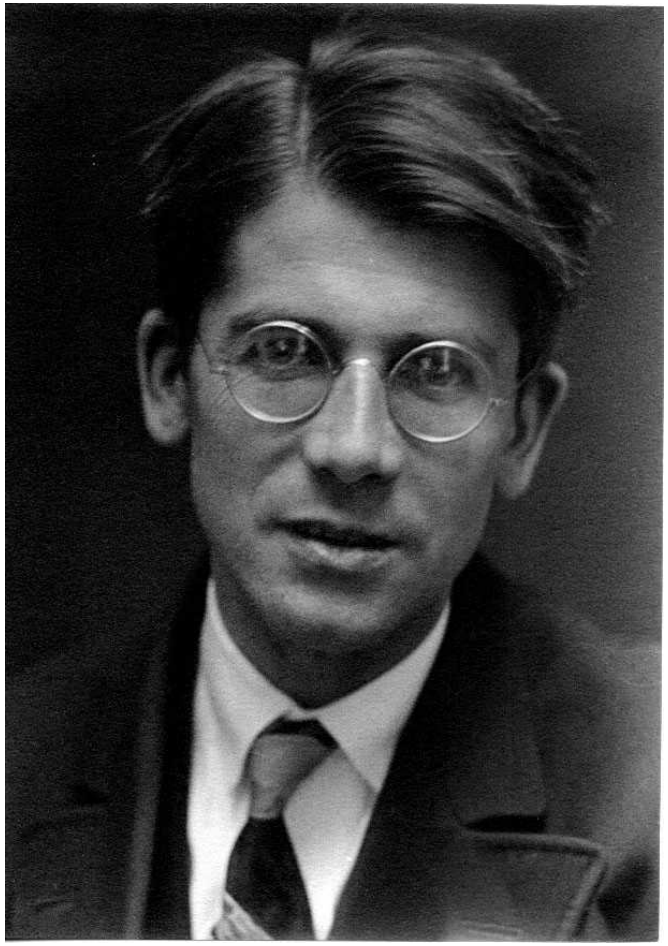

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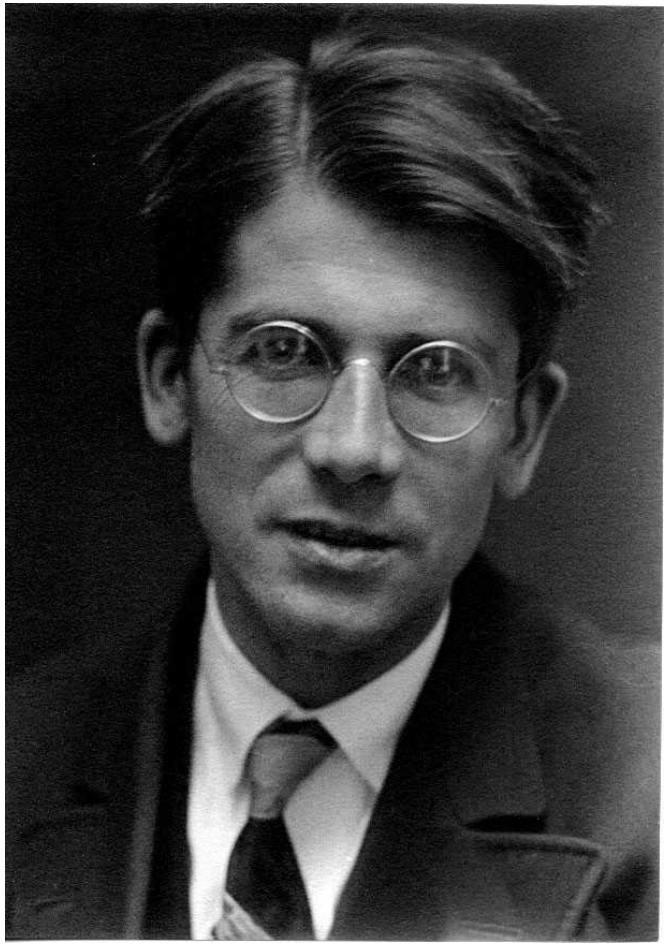

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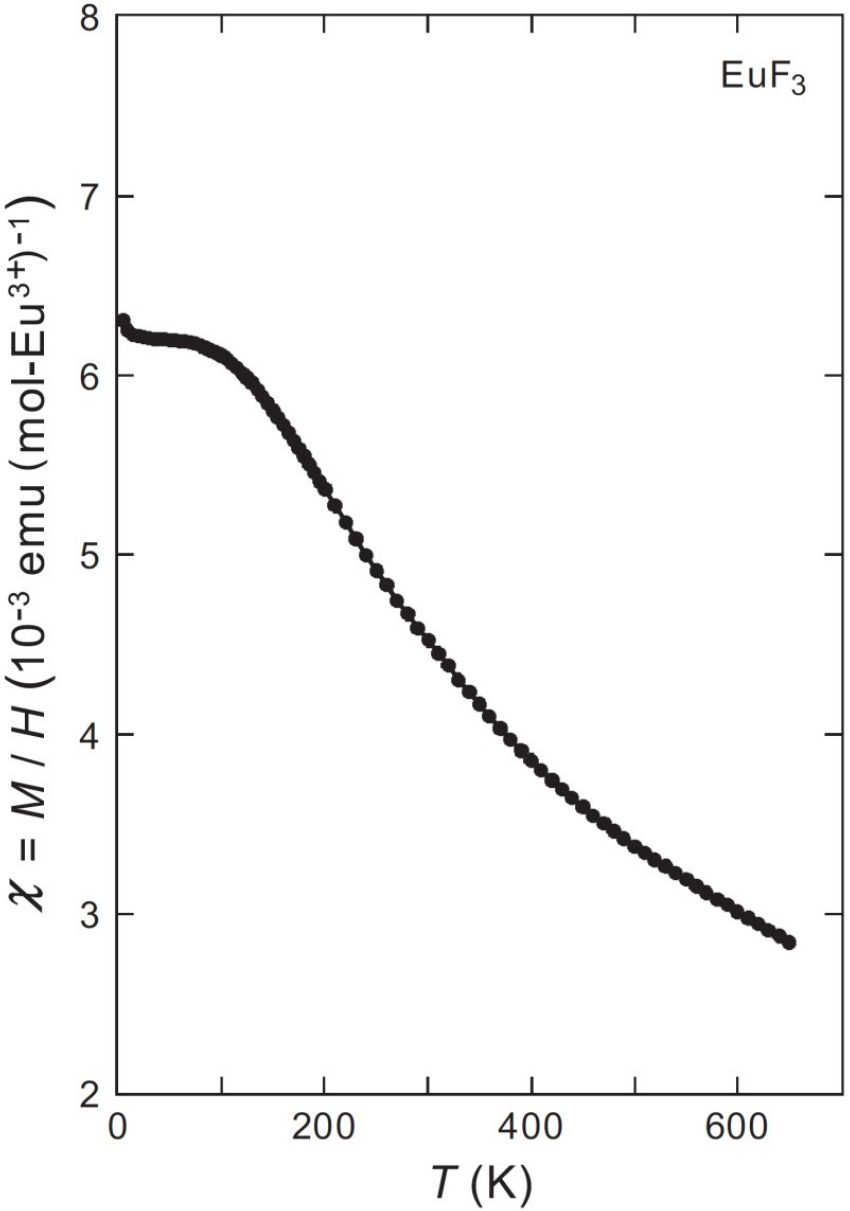

J. Phys. Chem. Solids 71, 1592 (2010)

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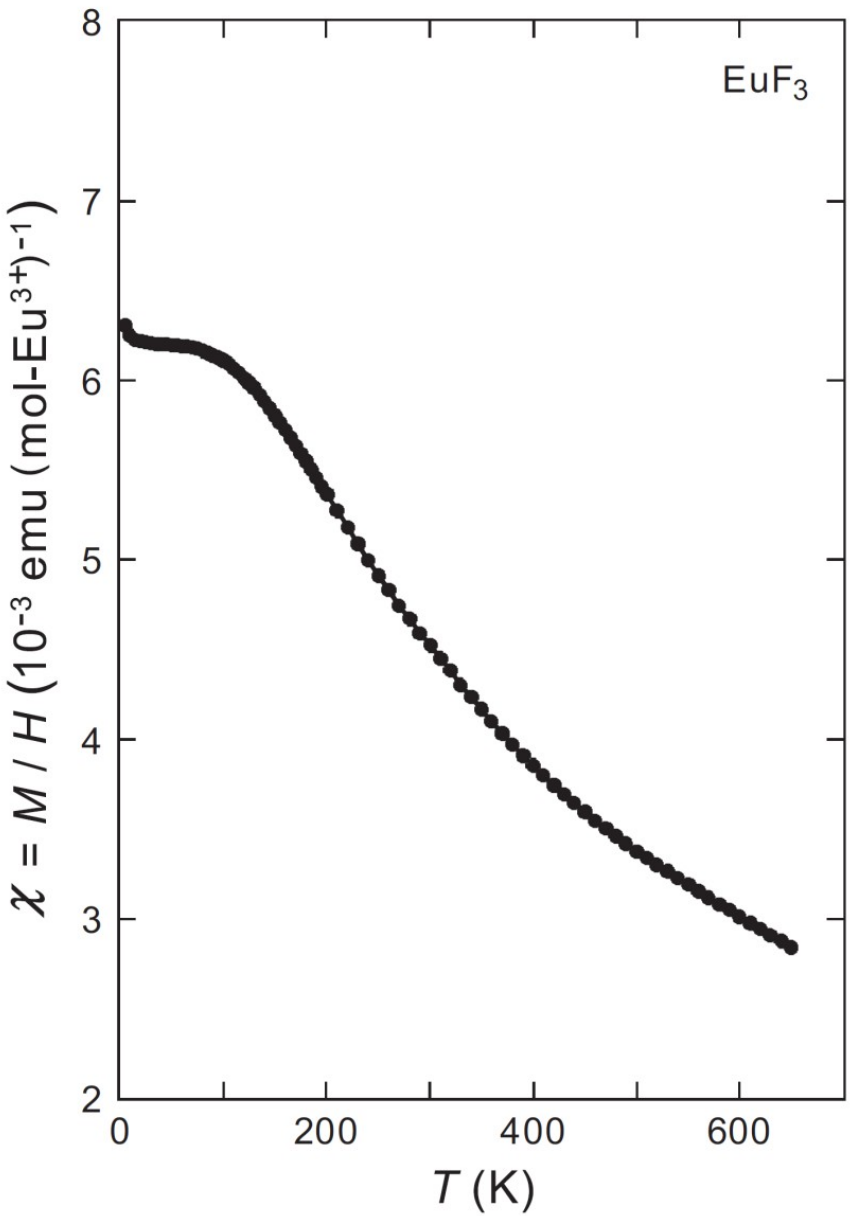

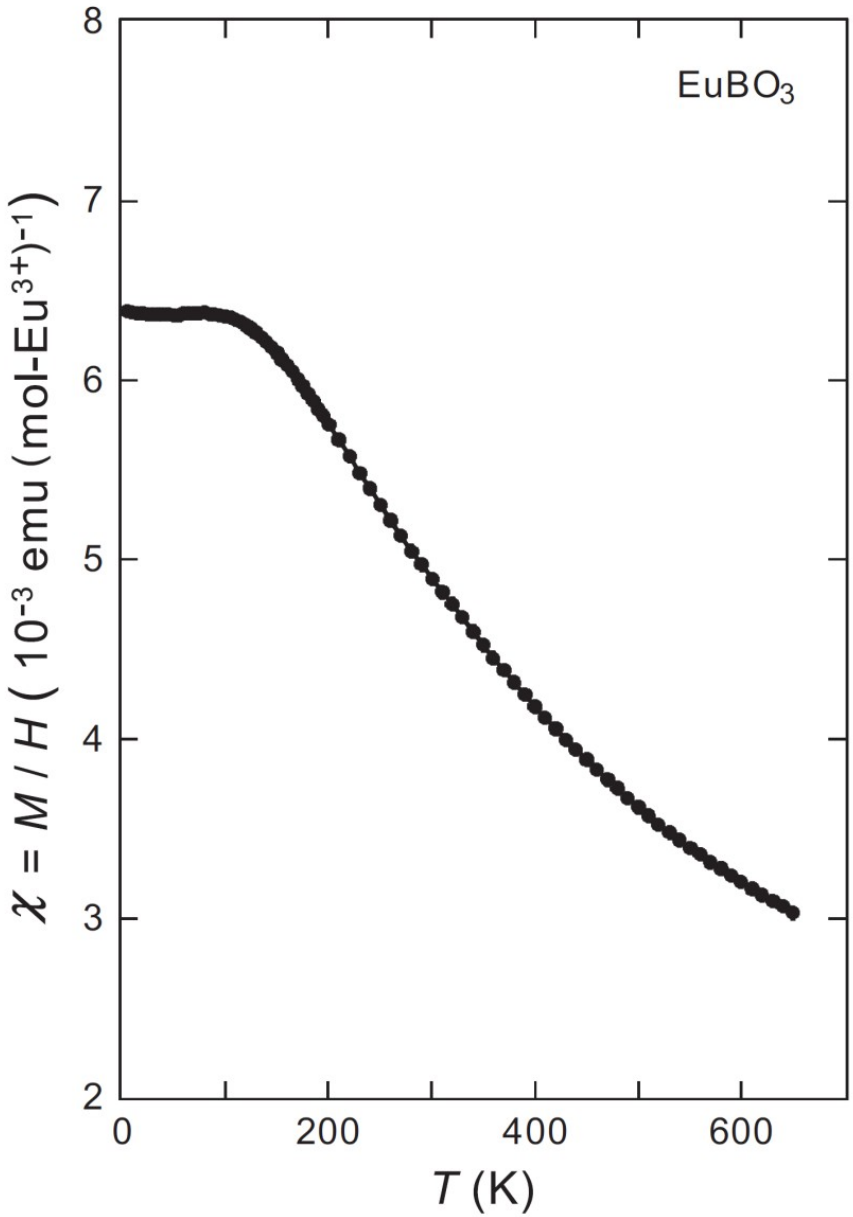

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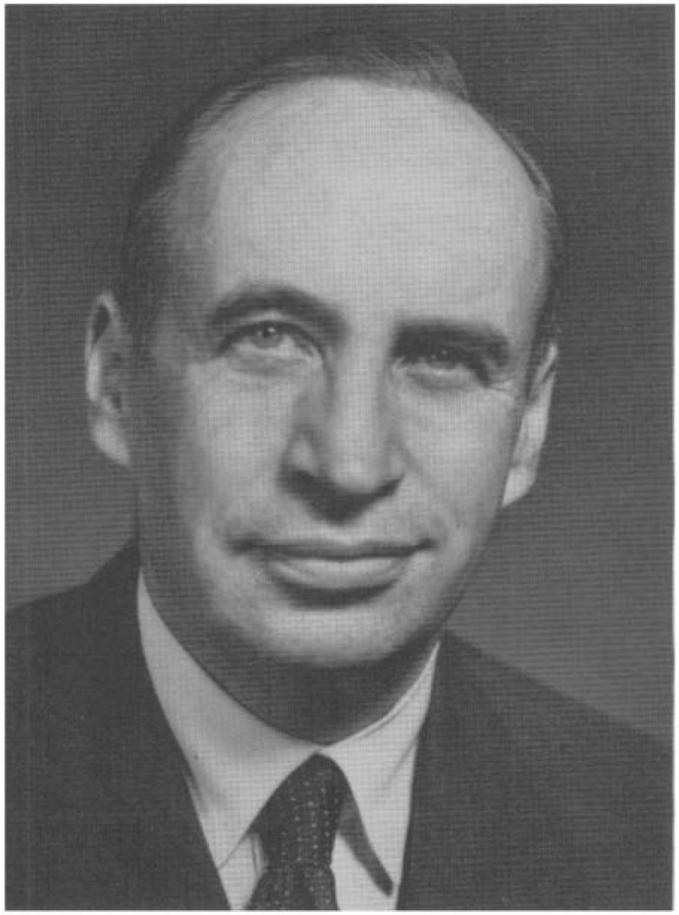

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- 1940's: development of microwave radars
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- 1977: Nobel prize in physics for "investigations of the electronic structure of magnetic and disordered systems"

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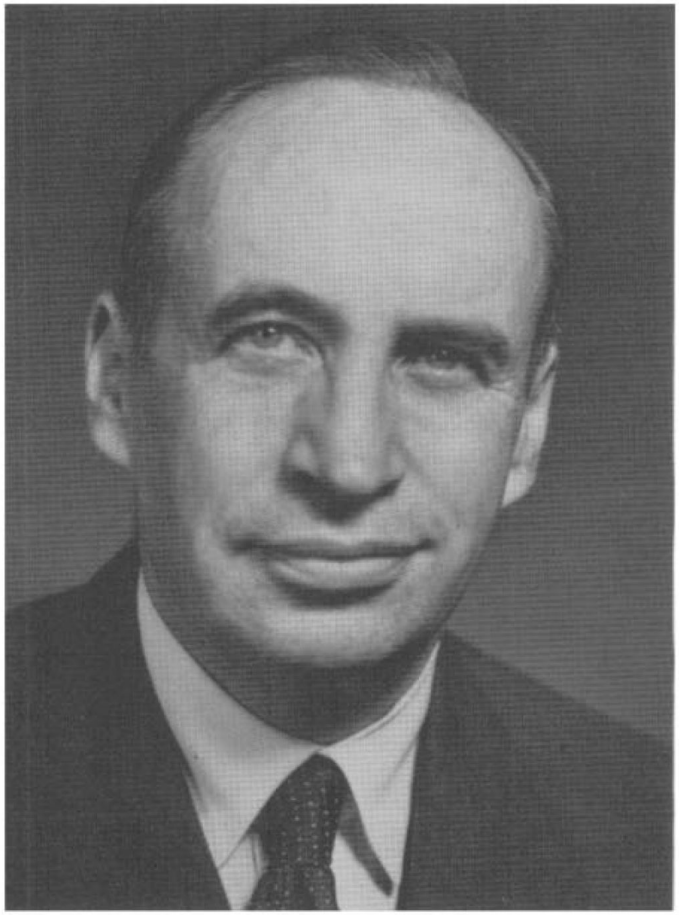

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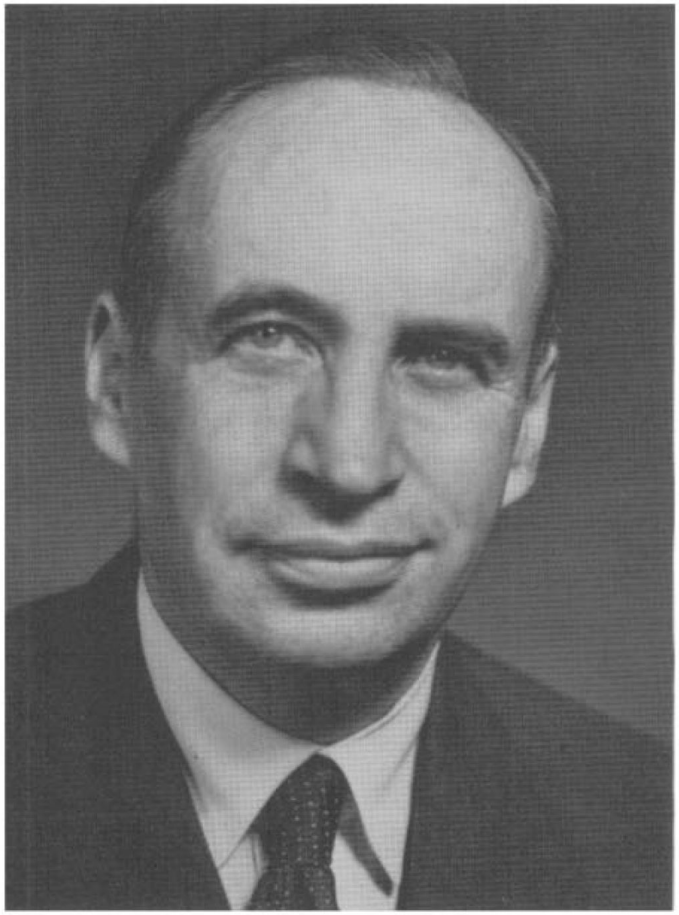

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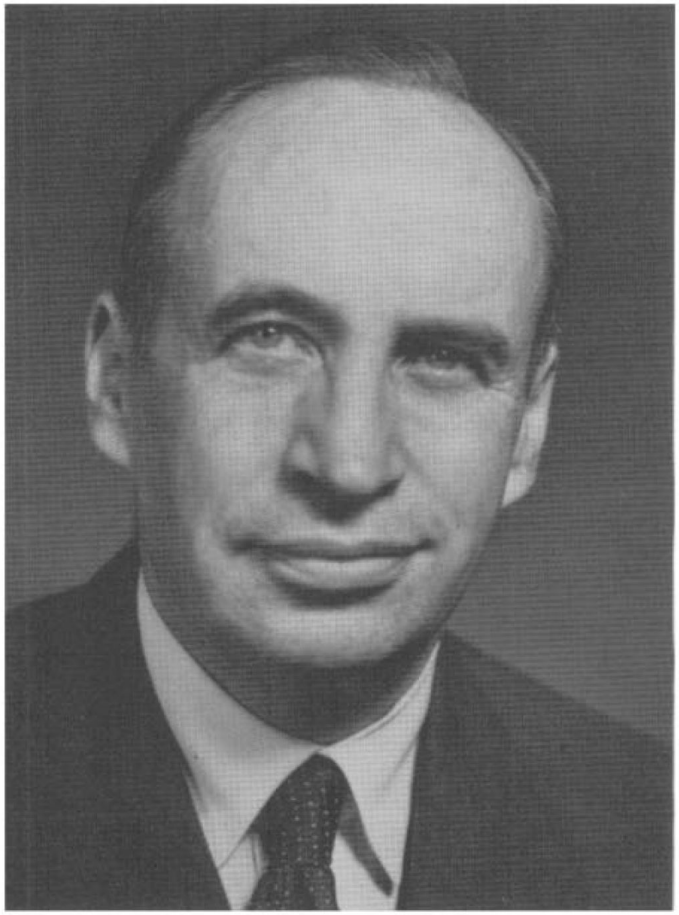

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"**Quantum mechanics** is the key to understanding magnetism.
When one enters the first room with this key, there are unexpected rooms beyond, but it is always the master key that unlocks each door"

Van Vleck's Nobel lecture (1977)