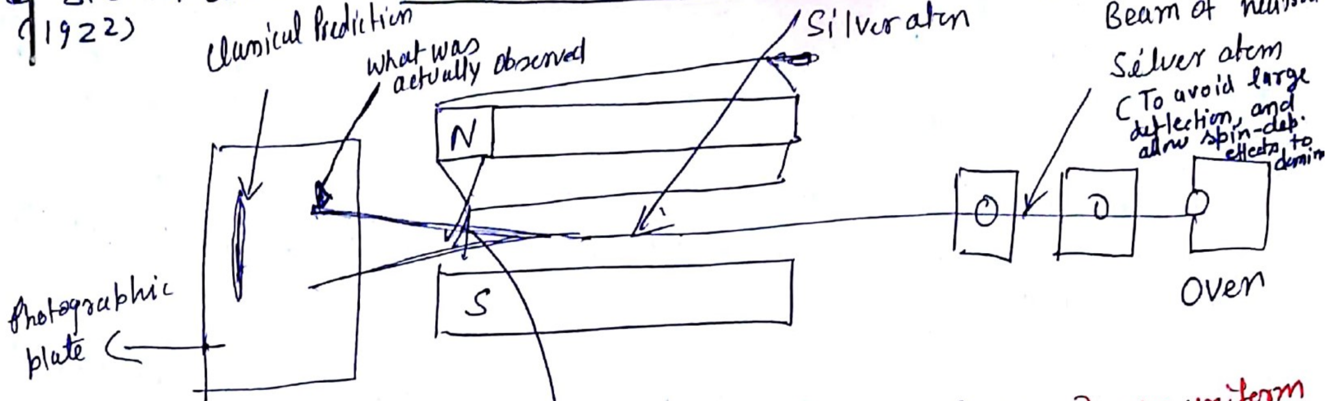
German physicists Stern & Gerlach (1922)

Stern- Gerlach experiment - $_{47}Ag$

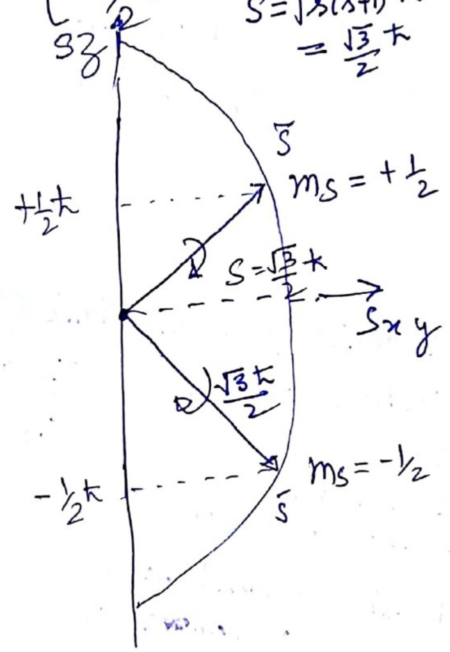


$S_z = m_s\hbar = \pm\frac{1}{2}\hbar$

Inhomogeneous mag. field ? (Non-uniform mag. field)

$S_z \begin{cases} +\frac{1}{2}\hbar \\ -\frac{1}{2}\hbar \end{cases}$

$S = \sqrt{s(s+1)}\,\hbar = \frac{\sqrt{3}}{2}\hbar$



In a uniform magnetic field, such a dipole would experience a torque tending to align it with the field.

In an inhomogeneous field, however, each "pole" of the dipole is subject to a force of different magnitude and therefore there is a resultant force on the dipole that varies with its orientation relative to the field.

⇓

Classically, all orientations should be present in a beam of atoms. The result would merely be a broad trace. Stern and Gerlach found, however that the initial beam split into two distinct parts that correspond to the two opposite spin orientations in the magnetic field permitted by space quantization.

Spin magnetic moment $\mu_s = -\frac{e}{m}S$

The possible components of μ_s along any axis, say the z-axis, are ~~there force~~ therefore limited to

z Component of spin magnetic moment $\mu_{sz} = \pm\frac{e\hbar}{2m} = \pm\mu_B$

$\mu_B \rightarrow$ Bohr magneton $(= 9.274\times10^{-24}\ J/T = 5.788\times10^{-5}\ eV/T)$

Spin magnetic	m_s	$-\frac{1}{2}, +\frac{1}{2}$ (spin down, spin up)	Electron spin direction

$$|\psi\rangle = c_1 \, |\psi_{j=+\frac{\hbar}{2}}\rangle + c_2 \, |\psi_{j=-\frac{\hbar}{2}}\rangle$$

which
to d

The screen reveals discrete points of accumulation rather than a continuous distribution, owing to the quantum nature of spin.

↓

This experiment proof reality of angular momentum quantization in all atomic-scale systems.

↓

Stern-Gerlach expt. allowed scientists to observe separation between discrete quantum states for the first time in the history of science.

(N) 47 electrons; 46 of them form a spherically symmetric charge distribution and the 47th electron occupies a 5s orbital. ↓ $l=0$.

Classically → Continuous band

Schrödinger → If the atoms had an orbital angular momentum l,
↓
we should expect split into an odd (discrete) number of $2l+1$ components.

Suppose atom is in g.s. $l=0$ → one spot

$l=1 (5p)$ → 3 spots

⇓

~~for~~ ~~So~~ Thus neither classical nor Schrödinger's wave theory is correct.

Also in hydrogen experimentally in their g.s ($l=0$) → no splitting expected (but still two spots)

⇓

Instead, ~~steal~~ it split into two distinct components.

⇓

Conclusions

In addition to its orbital angular momentum, the electron possesses an intrinsic angular momentum.

which, unlike the orbital angular momentum, has nothing to do with spatial degrees of freedom

$\Downarrow$

By analogy with earth, which consist of orbital motion around the Sun and an internal rotational or spinning motion about its axis.

$\Downarrow$ For matter

The electron or, for that matter, any other microscopic particle may also be considered to have some sort of internal or intrinsic spinning motion.

$\Downarrow$

Unlike the orbital angular momentum, the spin cannot be described by a differential operator.

From classical theory of electromagnetism, an orbital magnetic dipole moment is generated with the orbital motion of a particle of charge q.

$$\vec{\mu}_L = \frac{q}{2mc} \vec{L}$$

Spin mag. moment (cannot be derived classically), but with analogy

$$\vec{\mu}_s = -g_s \frac{e}{2m_e c} \vec{S},$$