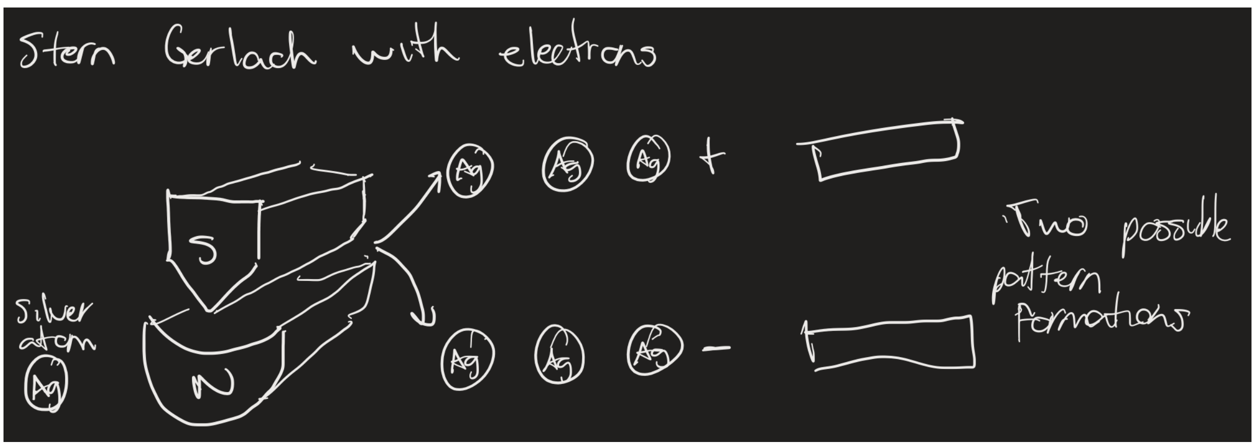
## Spin

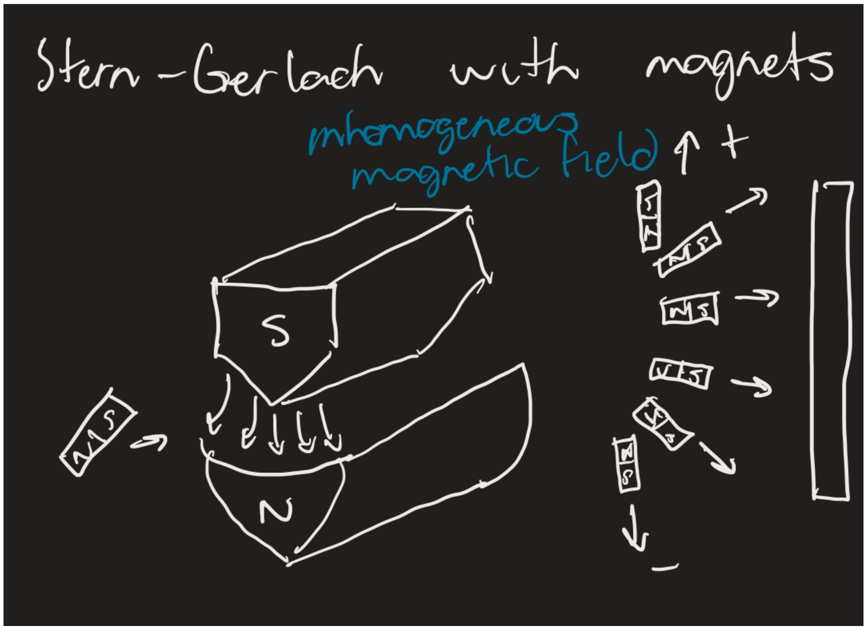
Spin is known as a physical property that every atomic particle possesses: angular momentum. Half spins are related to Fermions contrary to integers, associated with Bosons. But is it measurable? The answer is yes, not at the same time with position due to Heisenberg's uncertainty principle, but yes. This was achieved with the Stern-Gerlach experiment.

### ***Stern-Gerlach Experiment***

Silver is an atom conformed by 47 electrons, indicated by its electronic configuration: 1s2 2s2 2p6 3s2 3p6 4s2 3d10 4p6 4d10 **5s1**. This last valence electron can be, by Pauli exclusion and minimum energy principles, in a positive or negative state, or superpositioned. Thus, silver atoms are passed through an inhomogeneous magnetic field, forcing them to change their state to either a plus or minus one. In classical models, using common N->S magnets, measures should create a homogeneous vertical line, however, when using quantum particles such as electrons, only two random patterns are observed, representing plus or minus spin. Wavefunction for spins should be represented as next, where both C1 and C2 are amplitudes.

$$|\psi\rangle = C_1|\psi_{n=+\frac{\hbar}{2}}\rangle + C_2|\psi_{n=-\frac{\hbar}{2}}\rangle$$






***Spin Operators***

Operators in QM are very important, and one of them is directly related to spin: Pauli matrices and S operators. These ones obey commutation relations and are represented as $\hat{S} = \frac{\hbar}{2}\sigma$ and directly affect x, y and z axis:

$$\sigma_x = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \quad \sigma_y = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}, \quad \sigma_z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}.$$