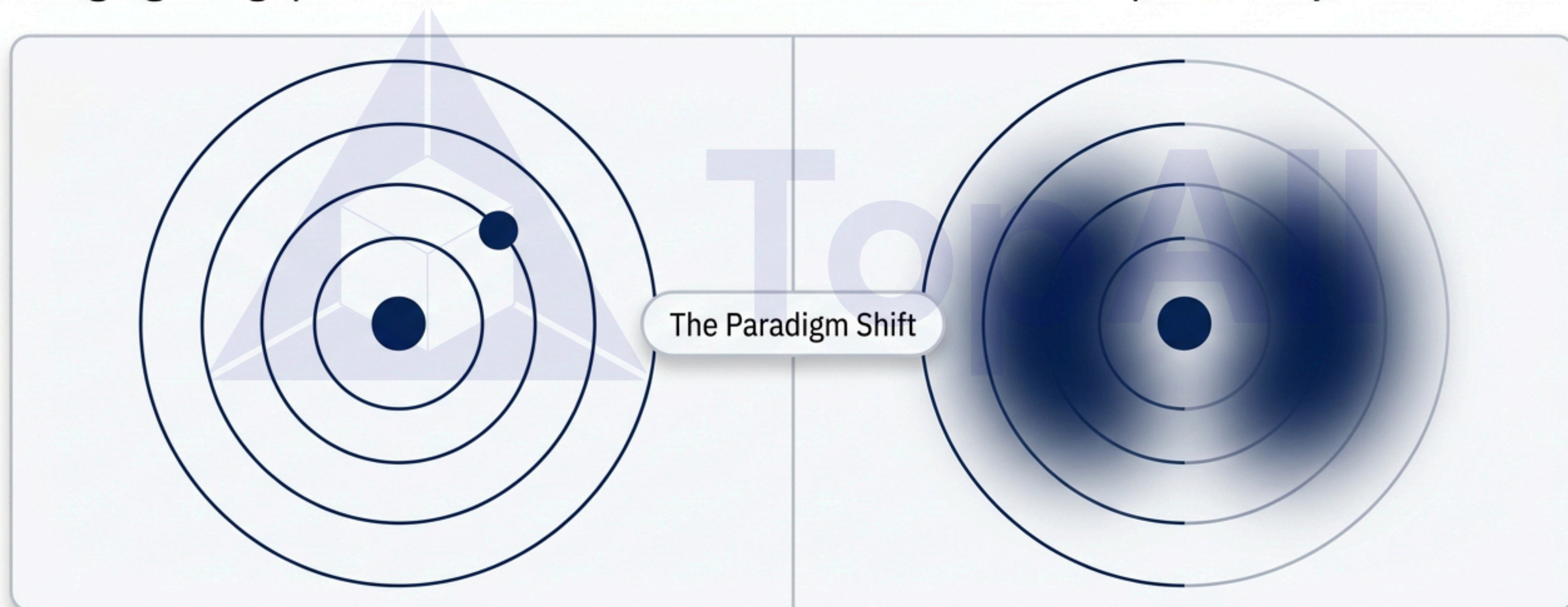


2.5 Towards Quantum Mechanical Model of Atom

Bridging the gap from classical orbits to the mathematics of probability.



Why Bohr Model Was Not Enough



What It Got Right

Quantized energy levels ($n = 1, 2, 3 \dots$)
Stability of the hydrogen atom
Explained the line spectrum of hydrogen



Where It Broke Down

Cannot explain spectra of multi-electron complex atoms.
Cannot explain the splitting of spectral lines in magnetic (Zeeman effect) or electric (Stark effect) fields.
Ignores the dual behavior of matter (wave-particle nature).
Contradicts the Heisenberg Uncertainty Principle by assuming exact, fixed paths.

Takeaway: Bohr's model treated the electron merely as a particle moving in a fixed, classical trajectory. A new model was required to account for the complexities of real atoms.

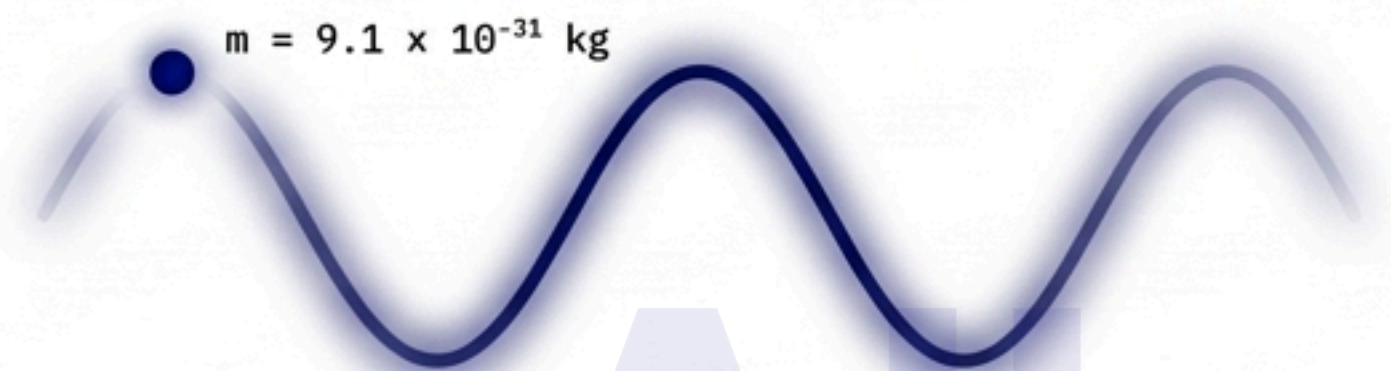
Matter Waves Enter the Picture

Macroscopic



Particle nature dominates. Wave nature is unobservable.

Microscopic



Dual behavior becomes critical.

de Broglie Relation

$$\lambda = h / (mv) = h / p$$

λ : Wavelength

h : Planck's constant

m : Mass

v : Velocity

p : Momentum

The Concept

Just like light (photons) has momentum and wavelength, subatomic particles exhibit dual behavior: they are both particles and waves.

The Catch

For heavy macroscopic objects, mass (m) is so large that wavelength (λ) is virtually zero. But for a tiny electron, its wave nature dictates its physical behavior.



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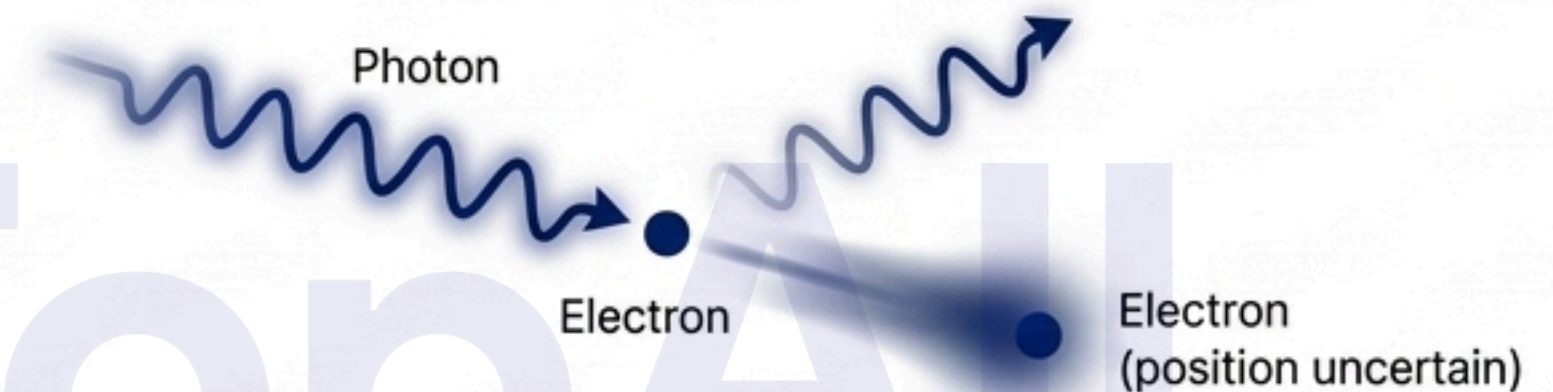
Uncertainty Replaces Exact Trajectory

Heisenberg Uncertainty Principle

"It is impossible to determine simultaneously, the exact position and exact momentum (or velocity) of an electron."

The Implication: If an electron is a wave spread out in space, it cannot have a precise, pinpoint location. Bohr's concept of an electron running on a fixed track is physically impossible.

The Observation Problem



To see an electron (find its position), we must hit it with a photon. This collision instantly alters the electron's velocity (changing its momentum).

$$\Delta x \cdot \Delta p \geq \frac{h}{4\pi} \quad \text{OR} \quad \Delta x \cdot m\Delta v \geq \frac{h}{4\pi}$$

[Δx : Uncertainty in position]

[Δp : Uncertainty in momentum]

Final Recap: from orbit concept to probability concept

Dimension	Bohr's Orbit (Classical)	Quantum Orbital (Modern)
What is it?	A well-defined circular path around the nucleus.	A 3D region of space where the probability of finding an electron is maximum.
Underlying Nature	Treats electron strictly as a particle.	Embraces the wave-particle duality of the electron.
Heisenberg Rule	Violates the Uncertainty Principle (assumes exact path).	Obeys the Uncertainty Principle (relies on probability).
Mathematical Representation	Simple classical geometry ($r = n^2 a_0$).	Wave function squared $ \psi ^2$ (probability density).

Conclusion: The Quantum Mechanical Model replaces the absolute certainty of “where the electron is” with the statistical probability of “where the electron is likely to be.”



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