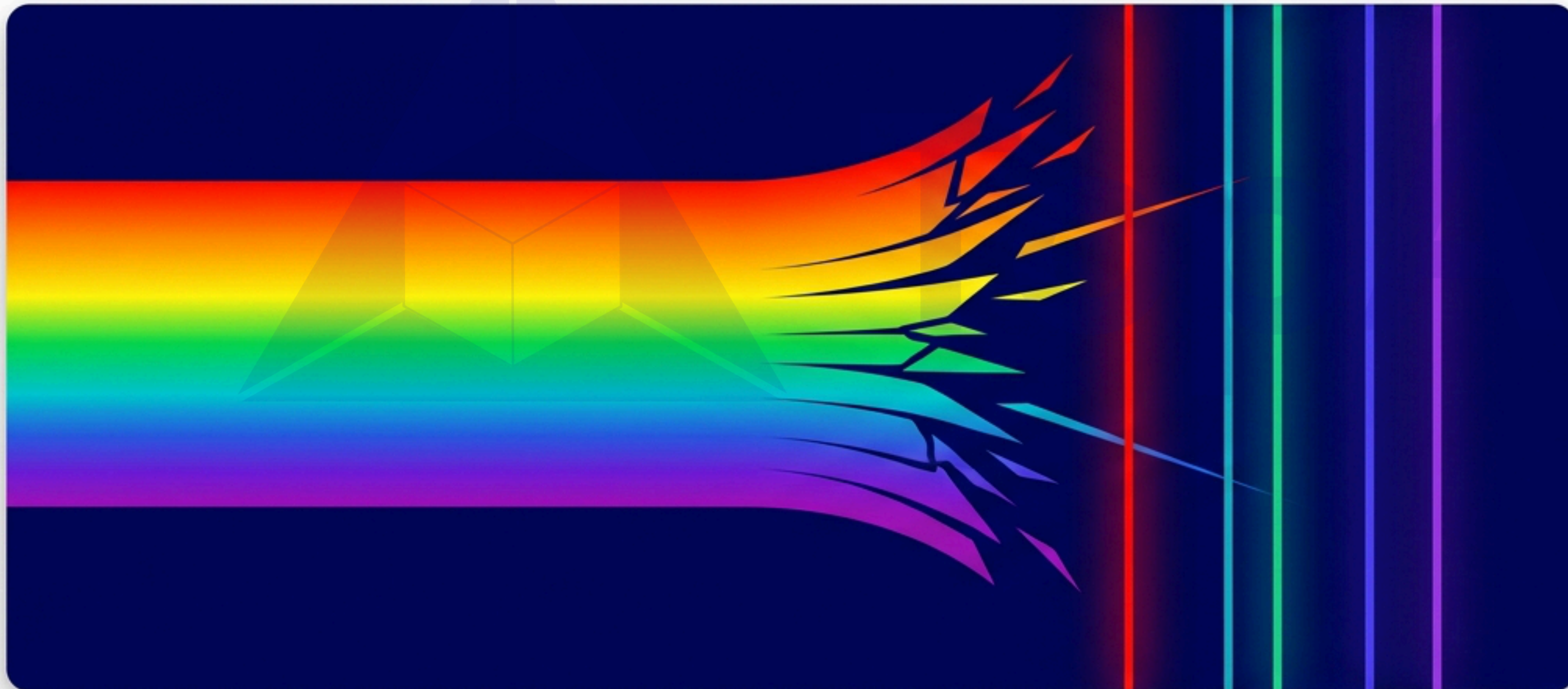


UNIT 2.3.3

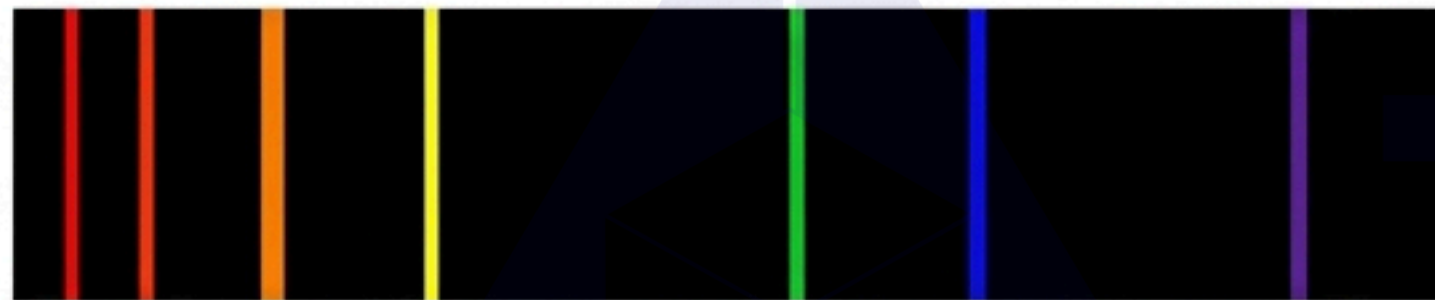
Atomic Spectra and the Line Spectrum of Hydrogen

From macroscopic observation to the mathematical abstraction of quantized energy states.



Emission Spectrum vs. Absorption Spectrum

Emission



Excited atoms returning to lower, more stable energy states emit radiation at specific wavelengths.

Absorption



White light passed through unexcited matter. Missing wavelengths represent specific radiation absorbed by atoms.

They are exact photographic negatives of each other. Atoms absorb and emit radiation at the exact same discrete frequencies.

THE SIGNIFICANCE

Why Line Spectra Matter



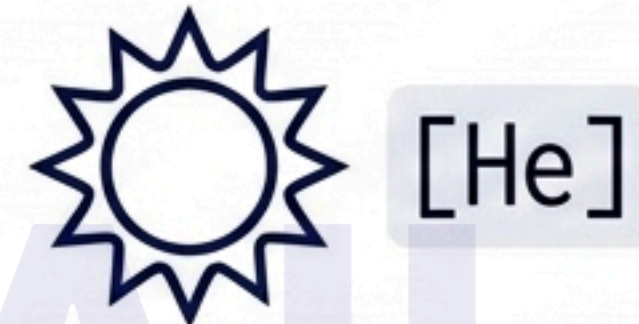
Atomic Fingerprints

Unlike continuous spectra, emission lines do not merge. Each element possesses an entirely unique line emission spectrum.



Chemical Analysis

Exact matching of spectral lines enables the immediate identification of unknown elements in a sample (pioneered by Robert Bunsen).



Discovery of Elements

Spectroscopic methods led directly to the discovery of Helium (He) in the sun, as well as Rubidium, Caesium, Thallium, and Gallium.



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EMPIRICAL PATTERNS

The Balmer Series (1885)



$\bar{\nu}$: Wavenumber
(number of wavelengths
per unit length).

$$\bar{\nu} = 109,677 \left(\frac{1}{2^2} - \frac{1}{n^2} \right) \text{ cm}^{-1}$$

109,677 : An exact, repeating
empirical constant.

n : An integer equal to or
greater than 3 ($n = 3, 4, 5...$).

Balmer proved that visible spectral lines are not random; they follow a strict, integer-based mathematical sequence.

GENERALIZED ABSTRACTION

The Rydberg Equation

$$\bar{\nu} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

Wavenumber of the transition (cm⁻¹)

Rydberg Constant: 109,677 cm⁻¹

Lower energy level integer

Higher energy level integer

Critical Constraints

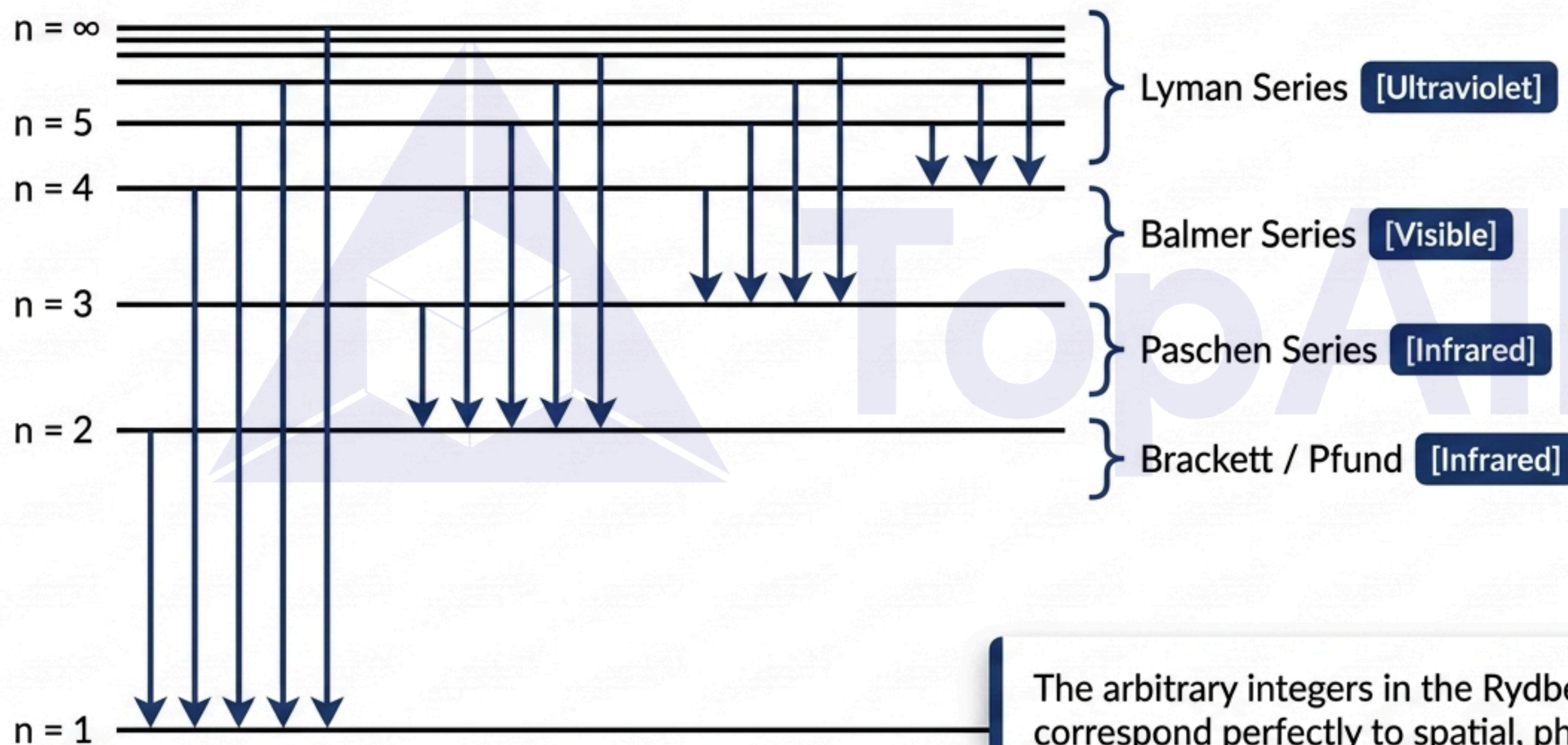
The Integer Rule

$n_1 = 1, 2, 3 \dots$

$n_2 = n_1 + 1, n_1 + 2 \dots$

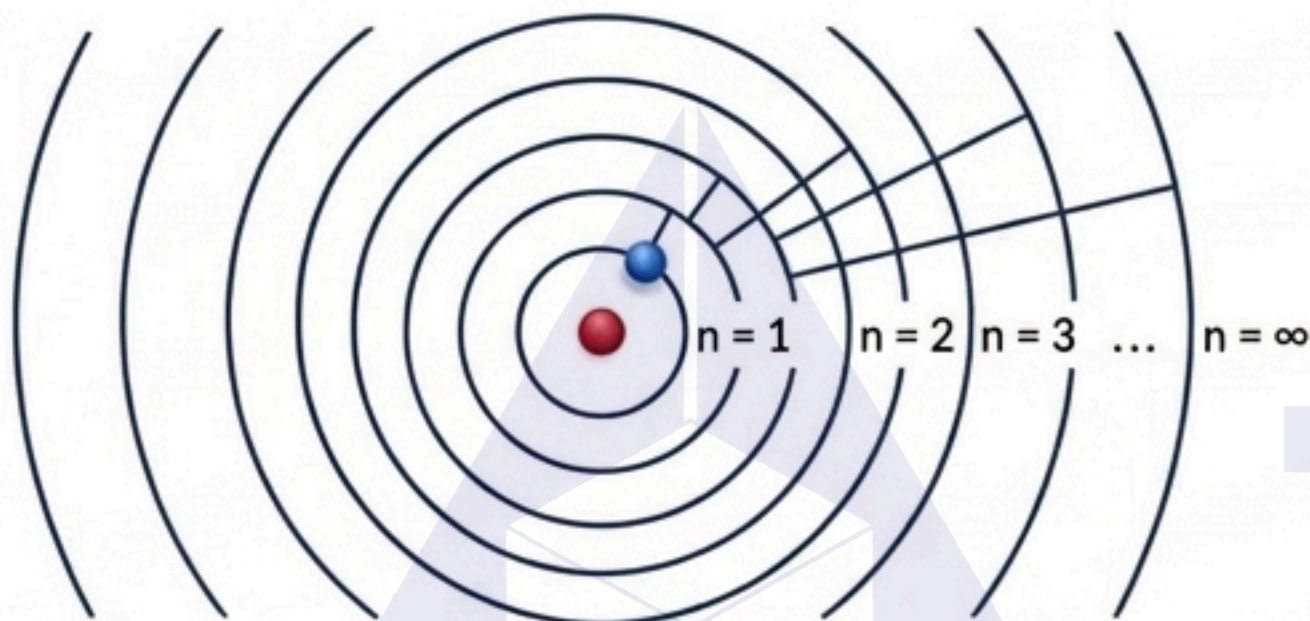
Johannes Rydberg expanded Balmer's specific visible-light formula to describe all possible series of lines in the Hydrogen spectrum.

Mapping the Hydrogen Spectral Series



The arbitrary integers in the Rydberg equation correspond perfectly to spatial, physical transitions between specific atomic energy states.

Hydrogen vs. Multi-Electron Atoms



Simplest System (1 Electron)

Why so many lines for one electron? A bulk sample of gas contains an enormous number of atoms in various possible excited states at any given moment.



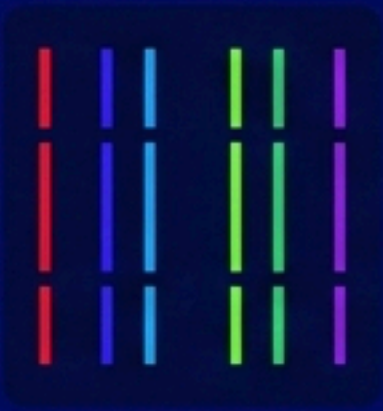
Multi-Electron Systems

Line spectra become vastly more complex as electron counts increase, due to overlapping energy transitions.

Despite structural complexity, all elements share a fundamental regularity in their spectra. This universal regularity demands a structural, quantum model of the atom to explain it.

THE “AHA!” CONCLUSION

Line Spectra Imply Quantized Energy



1. Observation

Spectra are composed of discrete, broken lines, not continuous rainbow gradients.



2. Mathematics

Emitted frequencies perfectly follow strict, integer-based mathematical rules.



3. Physical Reality

Therefore, electrons cannot exist in continuous or arbitrary states. They are restricted to specific, “quantized” energy levels.

$$\Delta E = E_2 - E_1 = h\nu$$

A specific photon is emitted only when an electron drops from one exact allowed energy state to another. Macro-level light proves micro-level quantum structure.



You've Learned the Theory.

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