ATOMIC STRUCTURE

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By

Dr. Supriya Kumari

J.L.N College,Dehri-on-Sone(Rohtas)

V.K.S.U,Ara

supriyachemu@gmail.com

ATOMIC STRUCTURE

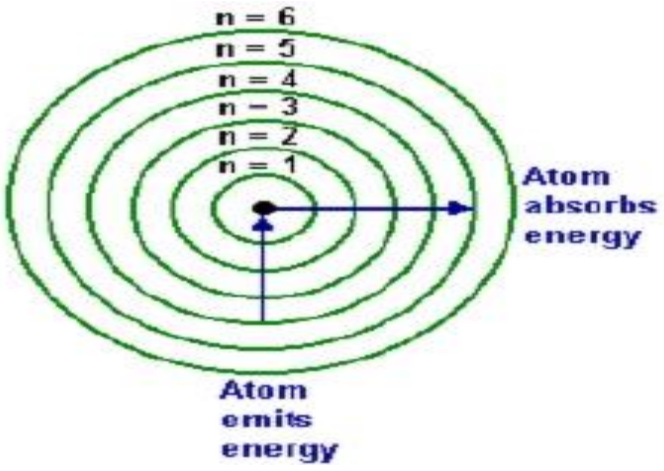
Limitation and Refinnement of Bohr's Theory ,Bohr-Sommerfeld Theory

BOHR'S MODEL OF ATOM

Niels Bohr introduced the **atomic Hydrogen model** in 1913.

He supported the planetary model, where electrons revolved around a positively charged nucleus(neutrons and protons) in a certain prescribed orbit.

When jumping from one orbit to another with lower energy, a light quantum is emitted.



BOHR'S ATOMIC MODEL

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ATOMIC STRUCTURE

FEATURES OF HYDROGEN SPECTRA

Hydrogen-spectrum:

- Niels Bohr explained the line spectrum of the hydrogen atom by assuming that the electron moved in circular orbits and that orbits with only certain radii were allowed.
- The orbit closest to the nucleus represented the ground state of the atom and was most stable; orbits farther away were higher-energy excited states.
- A single electron is responsible for each line
- Spectral lines are produced by atoms one at a time
- All the lines in the emission or absorption spectrum of hydrogen
- Each one corresponding to an allowed transition between quantum energy levels.

Origin of the hydrogen emission spectrum

- When unexcited, hydrogen's electron is in the first energy level the level closest to the nucleus.
- But if energy is supplied to the atom, the electron is excited into a higher energy level, or even removed from the atom altogether.

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Limitation and Refinnement of Bohr's theory

Limitation of Bohr's theory

- It could not explain the line spectra of atoms containing more than one electron. This theory could not explain the presence of multiple spectral lines .

- This theory could not explain the splitting of spectral lines in magnetic field (zeeman effect) and in electric field (Stark effect)

- The Bohr model gives an incorrect value $L=\hbar$ for the ground state orbital angular momentum.The angular momentum in the true ground state is known to be zero from experiment

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Limitation of Bohr's theory

- The Bohr Model is very limited in terms of size.
- Poor spectral predictions are obtained when larger atoms are in question.
- It cannot predict the relative intensities of spectral lines.
- It does not explain the Zeeman Effect, when the spectral line is split into several components in the presence of a magnetic field
- It was primarily for hydrogen atom.
- It couldn't elaborate spectra of multi-electron atoms.
- Wave nature of electron was not justified by the model (inconsistent with the de Broglie's hypothesis of dual nature of matter)
- It didn't illustrated molecules making process of chemical reactions.

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Refinements of Bohr's theory

German physicist Arnold Sommerfeld researched the **atomic model** of Niels Bohr first time in 1911 which showed the most accurate description of the atom at that time.

Postulate of Sommerfeld atomic model :

- Electrons were located in circular orbits, which had different energy levels, around the nucleus.
- The stationary orbits in which electrons are revolving around the nucleus in an atom are not circular but elliptical in shape.
- It is due to the influence of the centrally located nucleus. The electron revolves in elliptical path with nucleus at one of its foci.

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Refinements of Bohr's theory

- **Bohr–Sommerfeld theory** described the atom in terms of two quantum numbers,

- But Bohr had originally used only one quantum number. With this extension the theory provided an explanation of the Stark effect, the ordinary Zeeman effect, and the fine structure of the hydrogen spectrum.

- **Sommerfeld modified Bohr's theory** by quantizing the shapes and orientations of orbits to introduce additional energy levels corresponding to the fine spectral lines.

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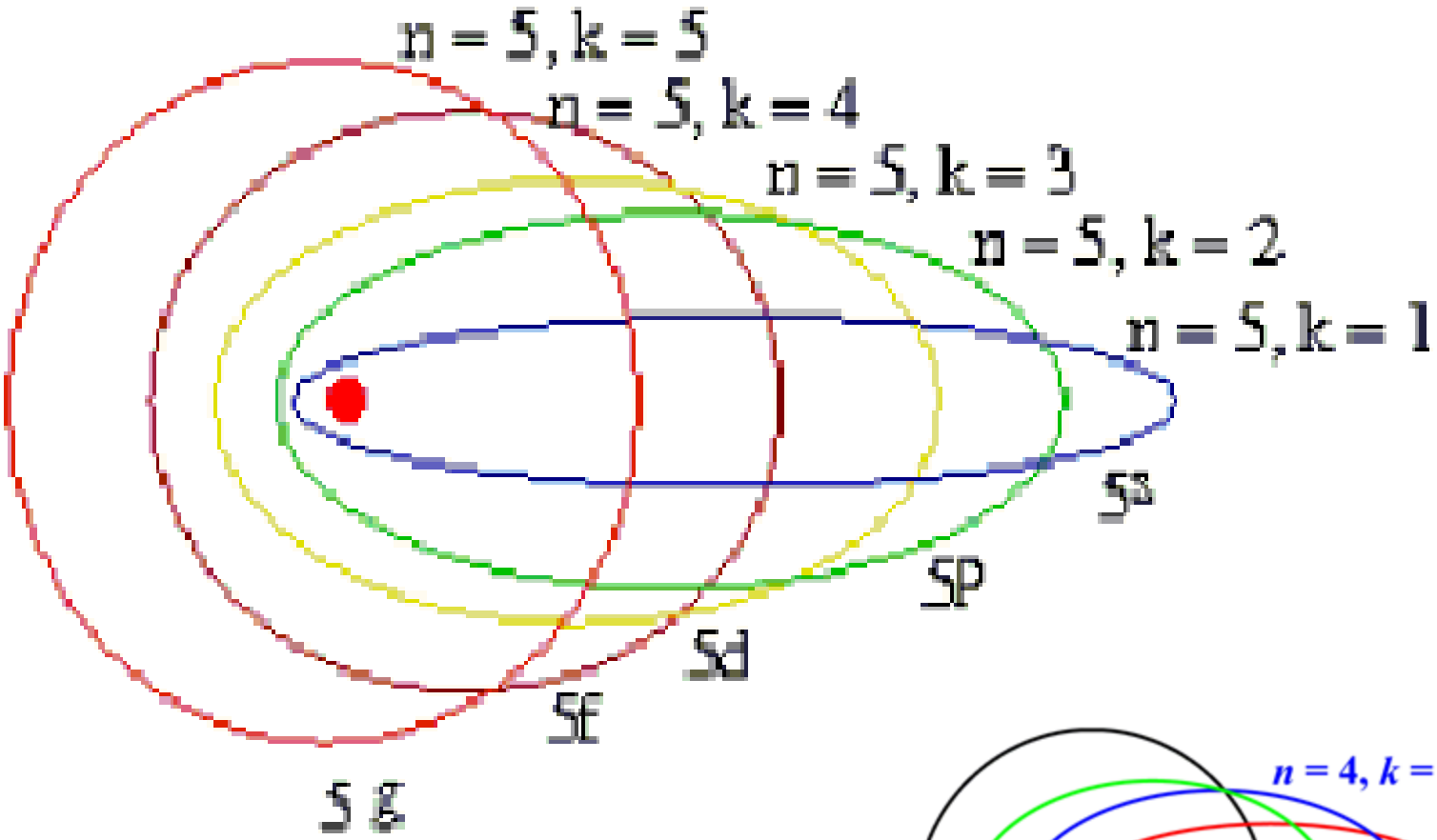

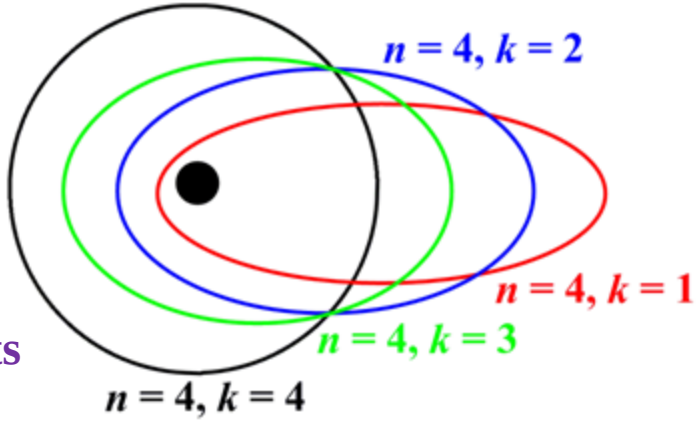

Sommerfeld elliptical orbits

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- Niels Bohr explained the line spectrum of the hydrogen atom by assuming that the electron moved in circular orbits and that orbits with only certain radii were allowed.
- The orbit which was closest to the nucleus represent the ground state of the atom and was most stable; orbits farther a line spectra of hydrogen were higher-energy excited states.
- The light emitted by hydrogen atoms is red because, of its four characteristic lines, the most intense line in its spectrum is in the red portion of the visible spectrum, at 656 nm.

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Rydberg formula

$$1/\lambda = R_H Z\,(1/n_1^2 - 1/n_2^2) \text{ where } n_2 > n_1$$

where .

Z is the atomic number of atom

n_1 is the principal quantum number of the lower energy level

n_2 is the principal quantum number of the upper energy level,

R_H is the Rydberg constant ($1.09737 \times 10^7\ m^{-1}$).

Note that this equation is valid for all hydrogen-like species, i.e. atoms having only a single electron, and the particular case of hydrogen spectral lines is given by Z=1.

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- The emission spectrum of atomic hydrogen has been divided into a number of **spectral series**, with wavelengths given by the Rydberg formula. These observed spectral lines are due to the electron making transitions between two energy levels in an atom. The classification of the series by the Rydberg formula was important in the development of quantum mechanics.

- The energy differences between levels in the Bohr model, and hence the wavelengths of emitted/absorbed photons, is given by

- Used to predict the wavelegth of a spectral line in many chemical elements when the electron changes from one orbital to another or from higher to lower energy

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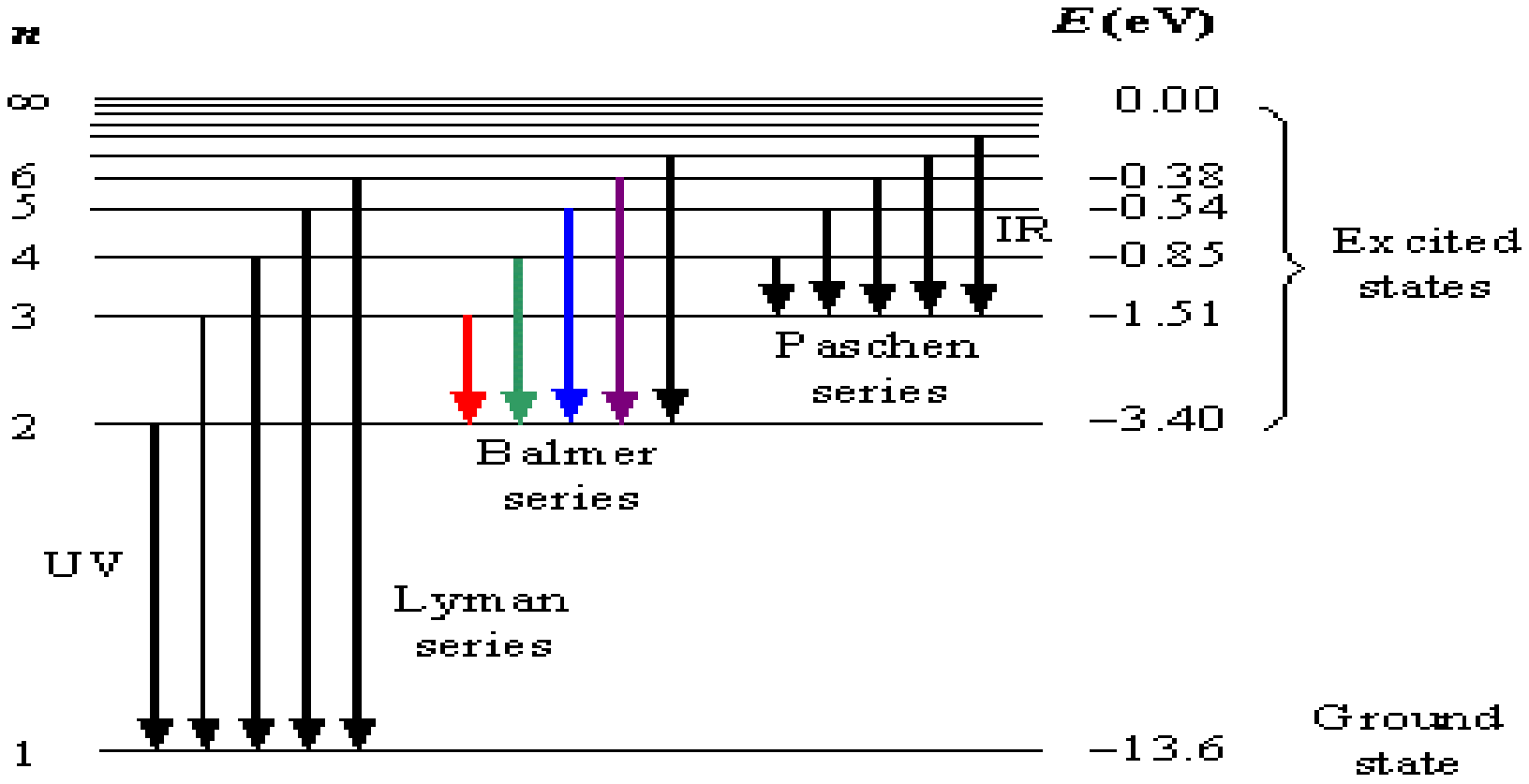

Energy levels of the hydrogen atom with some of the transitions between them that give rise to the spectral lines indicated

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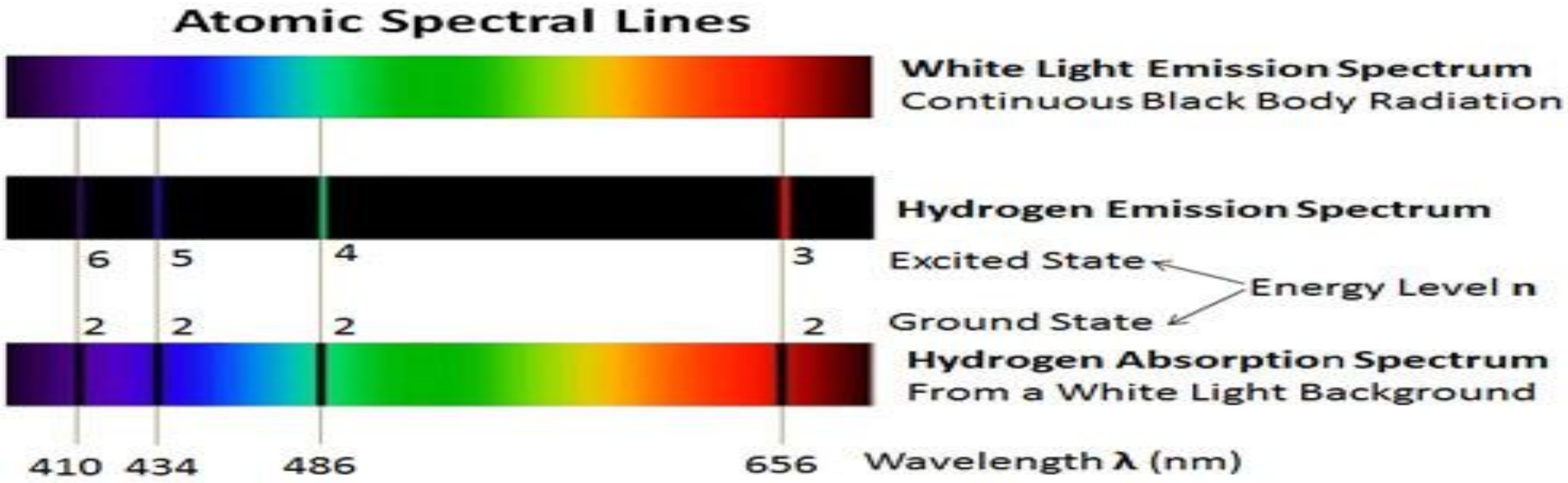

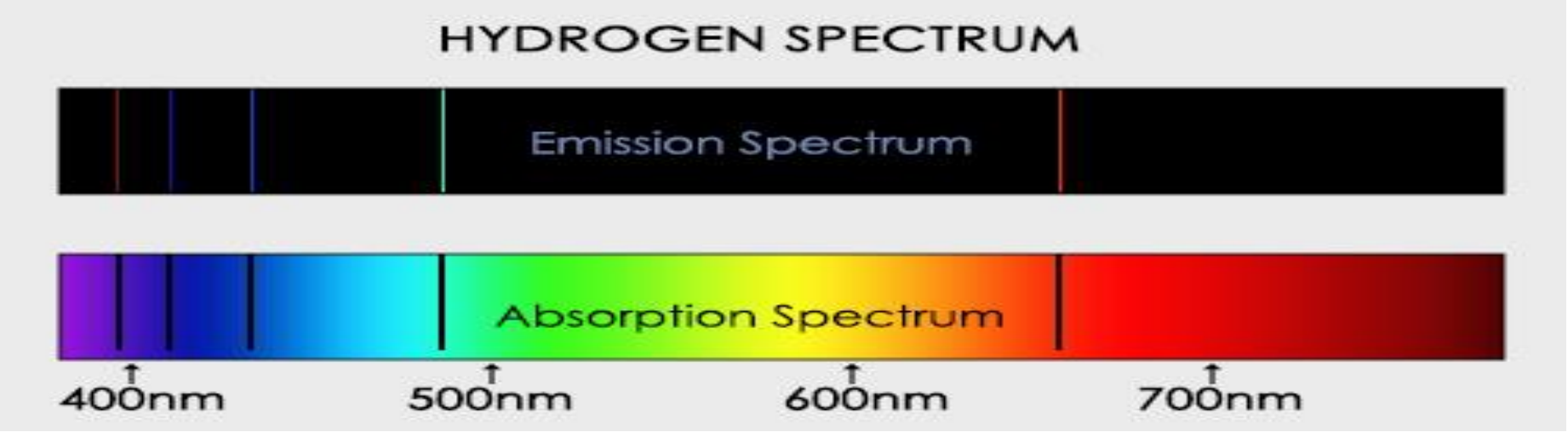

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Exercise

1. In the Bohr model of atom

Choose the correct option

A. Electrons (negatively charged) revolve around the positively charged nucleus in a definite these circular path

B. These circular path called as orbits or shells are stationary

C. Each orbit or shell has a fixed energy

D. All orbital shells have equal energy

2. A transition for an electron in the Bohr Hydrogen atom will be given.

Determine what energy/frequency/wavelength photon is emitted.

n=3 to n=1.

a) 8.1 eV.

b) 9.1 eV.

c) 10.1 eV.

d) 11.1 eV.

e). 12.1 eV.

Hints: ni>nf

ni=3 and nf=1