PHYS 111
1ST semester 1439-1440

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Lecture 23

Chapter 42

Atomic Physics

42.1 Atomic Spectra of Gases

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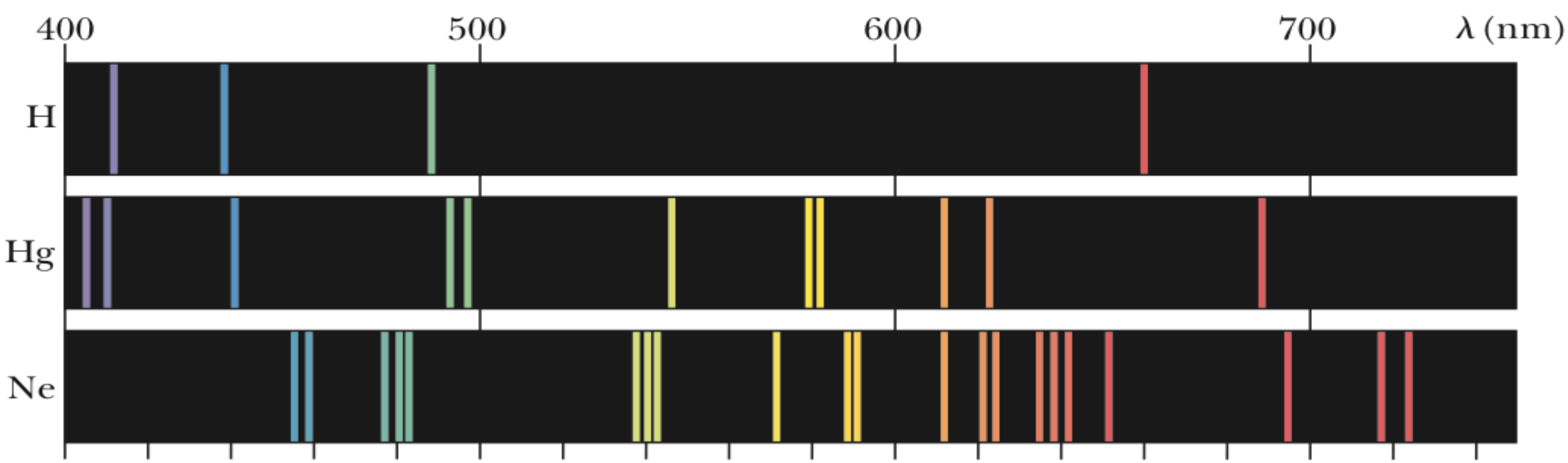
- All objects emit thermal radiation characterized by a *continuous* distribution of wavelengths.
- In contrast, the *discrete* **line spectrum** observed when a low-pressure gas undergoes an electric discharge. (Electric discharge occurs when the gas is subject to a potential difference that creates an electric field greater than the dielectric strength of the gas.)
- Observation and analysis of these spectral lines is called **emission spectroscopy.**

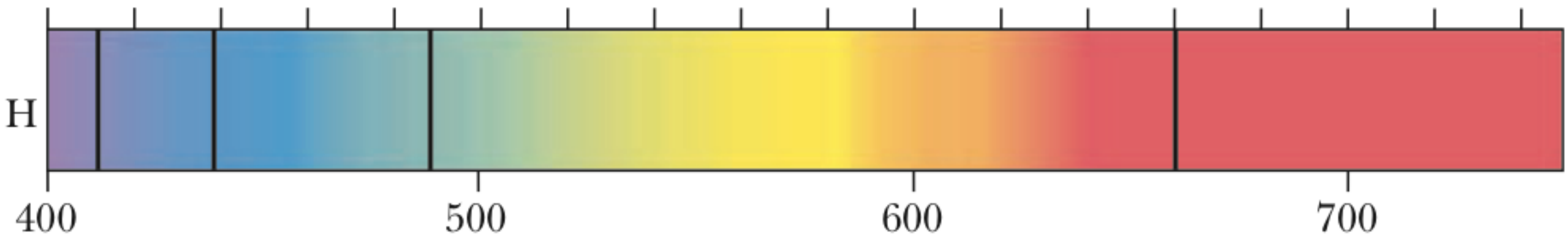
42.1 Atomic Spectra of Gases

- When the light from a gas discharge is examined using a spectrometer, it is found to consist of a few bright lines of color on a generally dark back-ground.
- The wavelengths contained in a given line spectrum are characteristic of the element emitting the light.
- The simplest line spectrum is that for atomic hydrogen.
- Because no two elements have the same line spectrum, this phenomenon represents a practical and sensitive technique for identifying the elements present in unknown samples.



42.1 Atomic Spectra of Gases

- Another form of spectroscopy very useful in analyzing substances is **absorption spectroscopy.**
- An absorption spectrum is obtained by passing white light from a continuous source through a gas or a dilute solution of the element being analyzed.
- The absorption spectrum consists of a series of dark lines superimposed on the continuous spectrum of the light source.



Balmer Series

- In 1885, Balmer found an empirical equation that correctly predicted the wavelength of four visible emission lines of hydrogen: H_α(red), H_β(blue-green), H_γ(blue-violet), and H_δ (violet)

- The four visible lines occur at the wavelengths 656.3 nm, 486.1 nm, 434.1 nm, and 410.2 nm. The complete set is called the **Balmer series.**

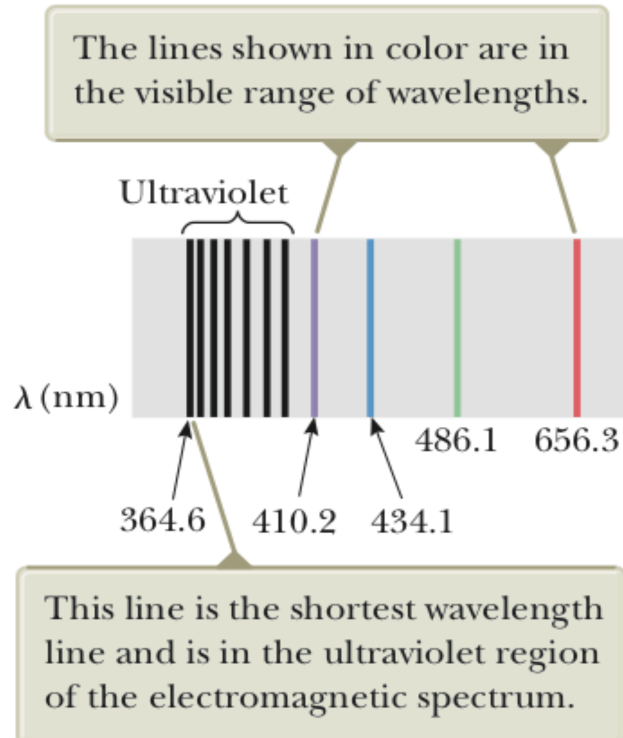


Figure 42.2 The Balmer series of spectral lines for atomic hydrogen, with several lines marked with the wavelength in nanometers. (The horizontal wavelength axis is not to scale.)

Balmer Series

- The wavelengths of these lines are given by

$$\frac{1}{\lambda} = R_H\left(\frac{1}{2^2} - \frac{1}{n^2}\right) \qquad n = 3, 4, 5, \ldots$$

- where R_H is a constant now called the **Rydberg constant** with a value of 1.097 373 2 x 10^7 m^{-1}
- The integer values of *n* from 3 to 6 give the four visible lines from 656.3 nm (red) down to 410.2 nm (violet).
- This equation also describes the ultraviolet spectral lines in the Balmer series if *n* is carried out beyond *n* = 6.
- The **series limit** is the shortest wavelength in the series and corresponds to $n \rightarrow \infty$, with a wavelength of 364.6 nm

Lyman, Paschen, and Brackett series

- Other lines in the spectrum of hydrogen were found following Balmer's discovery.
- These spectra are called the Lyman, Paschen, and Brackett series after their discoverers.
- The wavelengths of the lines in these series can be calculated through the use of the following empirical equations:

$$\frac{1}{\lambda} = R_H\left(1 - \frac{1}{n^2}\right) \quad n = 2, 3, 4, \ldots \qquad (42.2)$$ ◀ Lyman series

$$\frac{1}{\lambda} = R_H\left(\frac{1}{3^2} - \frac{1}{n^2}\right) \quad n = 4, 5, 6, \ldots \qquad (42.3)$$ ◀ Paschen series

$$\frac{1}{\lambda} = R_H\left(\frac{1}{4^2} - \frac{1}{n^2}\right) \quad n = 5, 6, 7, \ldots \qquad (42.4)$$ ◀ Brackett series

5. (a) What value of n_i is associated with the 94.96-nm spectral line in the Lyman series of hydrogen? (b) **What If?** Could this wavelength be associated with the Paschen series? (c) Could this wavelength be associated with the Balmer series?

(a) The Lyman series transitions all end in the ground state $n_f = 1$ Using the generalized Rydberg equation

$$\frac{1}{\lambda} = R_\mathrm{H}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$-\frac{1}{n_i^2} = \frac{1}{\lambda R_\mathrm{H}} - \frac{1}{n_f^2}$$

$$n_i = \left(\frac{1}{n_f^2} - \frac{1}{\lambda R_\mathrm{H}}\right)^{-1/2} = \left(1 - \frac{1}{94.96 \cdot 10^{-9}\ \mathrm{m} \cdot 1.10 \cdot 10^{7}\ \mathrm{m}^{-1}}\right)^{-1/2} = 5\,.$$

(b) This wavelength cannot have come from the Balmer ($n_f = 2$) or Paschen ($n_f = 3$) series because the shortest wavelength for any series is given in the limit that $n_i \to \infty$

$$\frac{1}{\lambda_\mathrm{min}} = \frac{R_\mathrm{H}}{n_f^2}$$

$$\lambda_\mathrm{min} = \frac{n_f^2}{R_\mathrm{H}}\,.$$

For the Balmer series $\lambda_\mathrm{min} = 365$ nm, and for the Paschen series $\lambda_\mathrm{min} = 820$ nm. Both of these series-minimum wavelengths are larger than the wavelength of our spectral line.