**Unit: 6.1**

**Introduction to Spectroscopy**

**Dr. D. Chakravarty.**

**1.7. Intensity of Spectral Lines:**

The intensity of light, over a narrow frequency range, is reduced due to absorption by the material and re-emission in random directions. Spectral lines are highly atom-specific, and can be used to identify the chemical composition of any medium capable of letting light pass through it.



**Figure:** Absorption lines for air, under indirect illumination

A spectral line is a dark or bright line in an otherwise uniform and [continuous spectrum](https://en.wikipedia.org/wiki/Continuous_spectrum), resulting from [emission](https://en.wikipedia.org/wiki/Emission_%28electromagnetic_radiation%29) or [absorption](https://en.wikipedia.org/wiki/Absorption_%28electromagnetic_radiation%29) of [light](https://en.wikipedia.org/wiki/Light) in a narrow frequency range, compared with the nearby frequencies. Spectral lines are often used to identify [atoms](https://en.wikipedia.org/wiki/Atom) and [molecules](https://en.wikipedia.org/wiki/Molecule). These "fingerprints" can be compared to the previously collected "fingerprints" of atoms and molecules, and are thus used to identify the atomic and molecular components of [stars](https://en.wikipedia.org/wiki/Star) and [planets](https://en.wikipedia.org/wiki/Planet), which would otherwise be impossible.

Spectral lines are the result of interaction between a [quantum system](https://en.wikipedia.org/wiki/Quantum_mechanics) (usually [atoms](https://en.wikipedia.org/wiki/Atom), but sometimes [molecules](https://en.wikipedia.org/wiki/Molecule) or [atomic nuclei](https://en.wikipedia.org/wiki/Atomic_nucleus)) and a single [photon](https://en.wikipedia.org/wiki/Photon). When a photon has about the right amount of energy to allow a change in the energy state of the system (in the case of an atom this is usually an [electron](https://en.wikipedia.org/wiki/Electron) changing [orbitals](https://en.wikipedia.org/wiki/Electron_configuration)), the photon is absorbed. Then it will be spontaneously re-emitted, either in the same frequency as the original or in a cascade, where the sum of the energies of the photons emitted will be equal to the energy of the one absorbed (assuming the system returns to its original state).

A spectral line may be observed either as an emission line or an absorption line. Which type of line is observed depends on the type of material and its temperature relative to another emission source. An absorption line is produced when photons from a hot, broad spectrum source pass through a cold material. The intensity of light, over a narrow frequency range, is reduced due to absorption by the material and re-emission in random directions. By contrast, a bright emission line is produced when photons from a hot material are detected in the presence of a broad spectrum from a cold source. The intensity of light, over a narrow frequency range, is increased due to emission by the material.

Spectral lines are highly atom-specific, and can be used to identify the chemical composition of any medium capable of letting light pass through it. Several elements were discovered by spectroscopic means, including [helium](https://en.wikipedia.org/wiki/Helium), [thallium](https://en.wikipedia.org/wiki/Thallium), and [caesium](https://en.wikipedia.org/wiki/Caesium). Spectral lines also depend on the physical conditions of the gas, so they are widely used to determine the chemical composition of [stars](https://en.wikipedia.org/wiki/Star) and other celestial bodies that cannot be analyzed by other means, as well as their physical conditions.

Mechanisms other than atom-photon interaction can produce spectral lines. Depending on the exact physical interaction (with molecules, single particles, etc.), the frequency of the involved photons will vary widely, and lines can be observed across the [electromagnetic spectrum](https://en.wikipedia.org/wiki/Electromagnetic_spectrum), from [radio waves](https://en.wikipedia.org/wiki/Radio_wave) to [gamma rays](https://en.wikipedia.org/wiki/Gamma_ray).

**Some frequently asking questions:**

* How does the intensity of the spectral line vary with wavelength ?

Intensity relates to amplitude and is unrelated to wavelength. Emission spectrum is a result of large number of light emitters in a given material, each radiating at a specific frequency.

* How many spectral lines are there ?

As there are 10 transitions and hence 10 spectral lines possible.

* Which element has the most spectral lines ?

Mercury: the strongest line, at 546 nm, gives mercury a greenish color. When heated in a electric discharge tube, each element produces a unique pattern of spectral `lines'.

* Why do spectral lines appear ?

Emission lines occur when the electrons of an excited atom, element or molecule move between energy levels, returning towards the ground state. For this reason, we are able to identify which element or molecule is causing the spectral lines.

* How do spectral lines work ?

A spectral line is a dark or bright line in an otherwise uniform and continuous spectrum, resulting from emission or absorption of light in a narrow frequency range, compared with the nearby frequencies. Spectral lines are often used to identify atoms and molecules.

* How many spectral lines does hydrogen have ?

When hydrogen electron jump from n=5 to n=1 in visible range then the following transitions are possible- 5 – 4, 5 – 4, 5 – 2, 5 – 1, 4 – 3, 4 – 2, 4 – 1, 3 – 2, 3 – 1, 2 – 1.
Hence, there are 10 spectral lines are possible.

* How do you identify a spectral line ?

A spectral line is like a fingerprint that can be used to identify the atoms, elements or molecules present in a star, galaxy or cloud of interstellar gas. If we separate the incoming light from a celestial source using a prism, we will often see a spectrum of colours crossed with discrete lines.

* Why do spectral lines get closer together ?

The lines in the spectrum of the hydrogen atom are caused by an electron moving from a higher energy level to a lower energy level. The shorter the wavelength of the light emitted, the greater its energy. The important point is that as the energy levels get higher, the levels get closer together.

* Why does hydrogen have so many spectral lines ?

Though a hydrogen atom has only one electron, it contains a large number of shells, so when this single electron jumps from one shell to another, a photon is emitted, and the energy difference of the shells causes different wavelengths to be released, hence, mono-electronic hydrogen has many spectral lines.

* Why are spectral lines different for each element ?

Each elements emission spectrum is distinct because each element has a different set of electron energy levels. The emission lines correspond to the differences between various pairs of the many energy levels. The lines (photons) are emitted as electrons fall from higher energy orbitals to lower energies. Hence, spectral lines are different for different element.

* What is the formula to calculate the maximum number of spectral lines ?

The formula to calculate the maximum possible number of spectral lines may be given as –

Possible Spectral Lines = (n2-n1).(n2-n1+1) / 2 .

Example:

When hydrogen electron jump from n=5 to n=1 in visible range then, we have the possible spectral lines of hydrogen = 10. ie.

n2 = 5 & n1 = 1 , Therefore, from the formula, (5 – 1). (5 - 1 + 1) / 2 = 4.5 / 2 = 20 / 2 = 10.

Thus, when hydrogen electron jump from n=5 to n=1 in visible range then the following 10 transitions are possible - 5 to 4, 5 to 3, 5 to 2, 5 to 1, 4 to 3, 4 to 2, 4 to 1, 3 to 2, 3 to 1 &

2 to 1.

Hence, there are 10 spectral lines are possible.

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*