CH 2252 Instrumental Methods of Analysis

Unit – I

www.msubbu.in

Electromagnetic Radiation

M. Subramanian

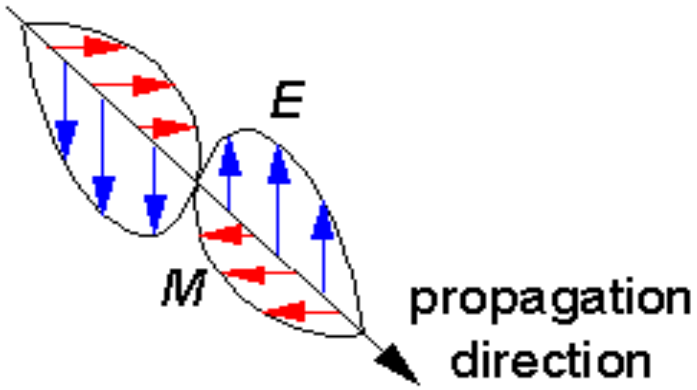
Assistant Professor
Department of Chemical Engineering
Sri Sivasubramaniya Nadar College of Engineering
Kalavakkam – 603 110, Kanchipuram (Dist)
Tamil Nadu, India
msubbu.in@gmail.com

Contents

- ELECTROMAGNETIC RADIATION: Regions and properties

Electromagnetic Radiation

- Electromagnetic radiation consists of discrete packets of energy, which we call photons.
- A photon consists of an oscillating electric field component, *E*, and an oscillating magnetic field component, *M*. The electric and magnetic fields are orthogonal (perpendicular) to each other, and they are orthogonal to the direction of propagation of the photon.
- The electric and magnetic fields of a photon flip direction as the photon travels. We call the number of flips, or oscillations, that occur in one secor



Properties of Electromagnetic Radiation

- All photons (in a given, non-absorbing medium) travel at the same velocity, *v*.
- The physical distance in the direction of propagation over which the electric and magnetic fields of a photon make one complete oscillation is called the wavelength, λ of the electromagnetic radiation.
- The relationship between the light velocity, wavelength, and frequency is:

$$v = \lambda \nu$$

- The electromagnetic nature of all photons is the same, but photons can have different frequencies
- The energy, E, of one photon depends on its frequency of oscillation:

$$E = h \nu = = h v / \lambda$$

where h is Planck's constant (6.62618×10^{-34} J·s).

Velocity of Light

- Electromagnetic waves travel through a vacuum at a constant velocity of 2.99792×10^8 m/s, which is known as the speed of light, c.

- The relationship between the speed of light, wavelength, and frequency is:

$$c = \lambda \nu$$

- When light passes through other media, the velocity of light decreases. Since the energy of a photon is fixed, the frequency of a photon does not change.

- Thus for a given frequency of light, the wavelength must decrease as the velocity decreases.

Refractive Index

- The decrease in velocity is quantitated by the refractive index, n, which is the ratio of c to the velocity of light in another medium, v:

$$n = c / v$$

- Since the velocity of light is lower in other media than in a vacuum, n is always a number greater than one.

- Refractive index is an intrinsic physical property of a substance, and can be used to monitor purity or the concentration of a solute in a solution.

- The refractive index of a material is measured with a refractometer, and is usually made versus air. If the precision warrants, the measurements can be corrected for vacuum. Note that the difference between nair and nvacuum is only significant in the fourth decimal place.

Refractive Index

medium	n*
air	1.0003
water	1.333
50% sucrose in water	1.420
carbon disulfide	1.628
diamond	2.417

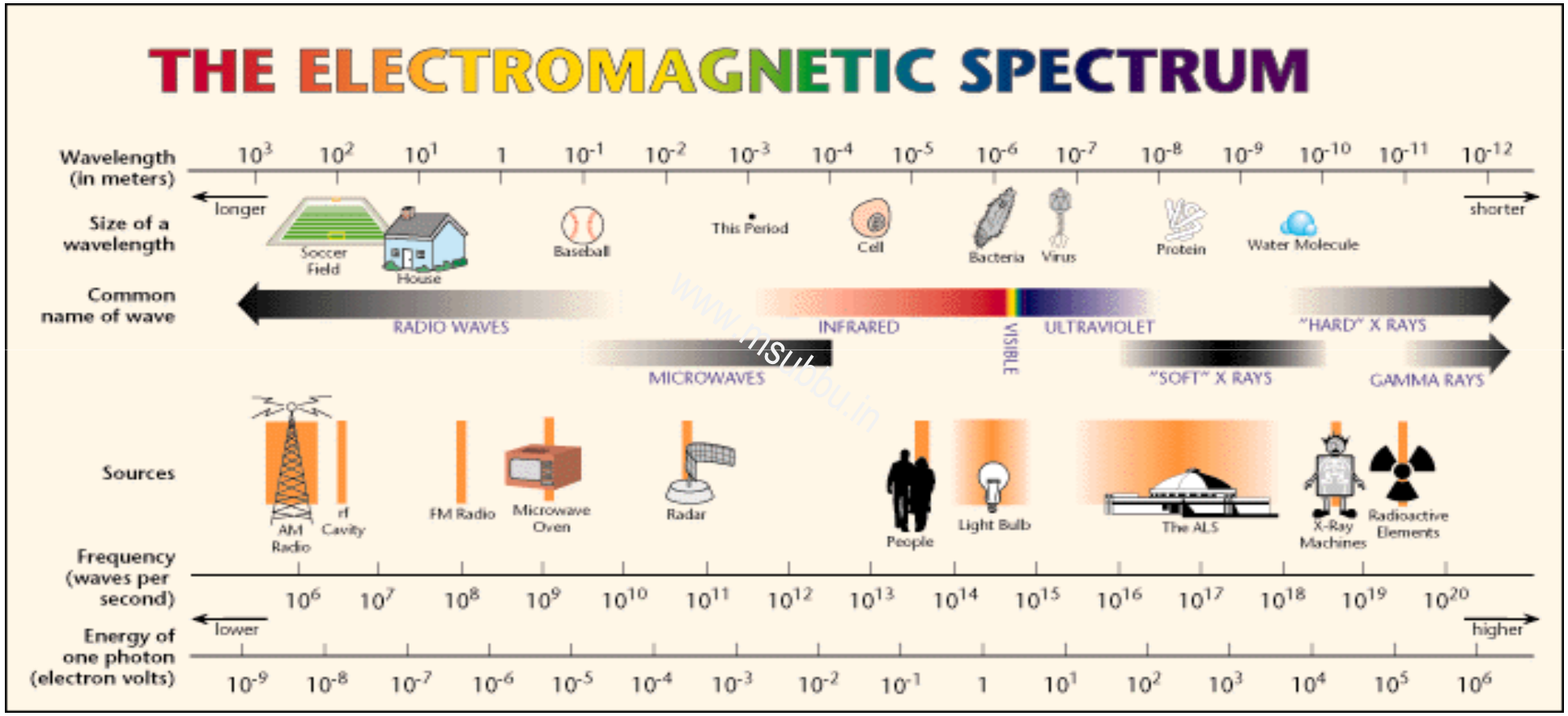
*measured with 589.3 nm light

Electromagnetic Spectrum

- For convenience in talking about electromagnetic radiation, we classify photons of different energies into different spectral regions.

- The photons in all of these regions have the same electromagnetic nature, but because of their very different energies they interact with matter very differently.

Type of Radiation	Frequency Range (Hz)	Wavelength Range
gamma-rays	10^{20}-10^{24}	<1 pm
X-rays	10^{17}-10^{20}	1 nm-1 pm
ultraviolet	10^{15}-10^{17}	400 nm-1 nm
visible	4-7.5x10^{14}	750 nm-400 nm
near-infrared	1x10^{14}-4x10^{14}	2.5 μm-750 nm
infrared	10^{13}-10^{14}	25 μm-2.5 μm
microwaves	3x10^{11}-10^{13}	1 mm-25 μm
radio waves	<3x10^{11}	>1 mm


THE ELECTROMAGNETIC SPECTRUM
Wavelength (in meters)
10^3 10^2 10^1 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12}
longer
shorter
Size of a wavelength
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
Common name of wave
RADIO WAVES
MICROWAVES
INFRARED
VISIBLE
ULTRAVIOLET
"SOFT" X RAYS
"HARD" X RAYS
GAMMA RAYS
Sources
AM Radio
rf Cavity
FM Radio
Microwave Oven
Radar
People
Light Bulb
The ALS
X-Ray Machines
Radioactive Elements
Frequency (waves per second)
10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20}
lower
higher
Energy of one photon (electron volts)
10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10^1 10^2 10^3 10^4 10^5 10^6

Wave number

- Wave number ($\bar{\nu}$)

$$\bar{\nu} = \frac{1}{\lambda}$$