MODERN ELECTRONIC THEORY OF ATOMS

CHM 101

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Classical Descriptions of Matter

- **John Dalton (1803)**
  - – Atoms are hard, indivisible, billiard-like particles.
  - – Atoms have distinct masses (what distinguishes on type of atom from another). All atoms of an element are the same.
- **JJ Thomson (1890s)**
  - – discovered charge-to-mass ratio of electrons
  - → atoms are divisible because the electrons are one part of atom
- **Ernest Rutherford (1910)**
  - – shot positively charged alpha particles at a thin foil of gold
  - → discovery of the atomic nucleus
- **James Maxwell (1873)**
  - – visible light consists of electromagnetic waves

ELECTROMAGNETIC RADIATION

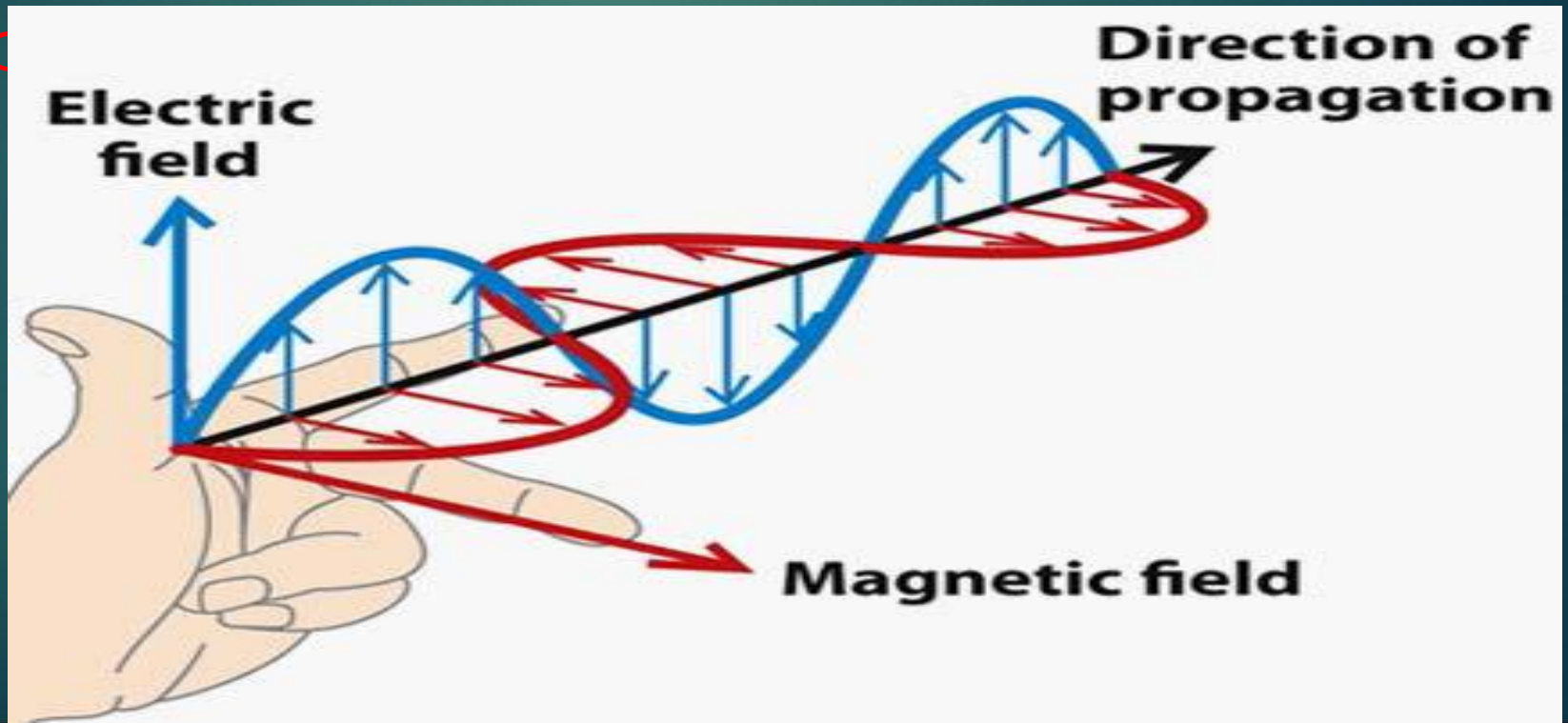
- Energy can be transmitted from one place to another by light popularly known as electromagnetic radiation.

- Light is a form of electromagnetic radiation, a type of energy that travels through space at a constant speed, known as the speed of light (symbol c): 2.998×10^8 m/s.

- While light may appear instantaneous to us, it is actually a wave traveling at a finite speed.
- Many kinds of electromagnetic radiation exist: X rays, microwaves, radio waves etc.

Theory of Electromagnetic Radiation

- The term electromagnetic comes from the theory proposed by Scottish scientist James Clerk Maxwell that radiant energy consists of waves with an oscillating electric field and an oscillating magnetic field, which are perp

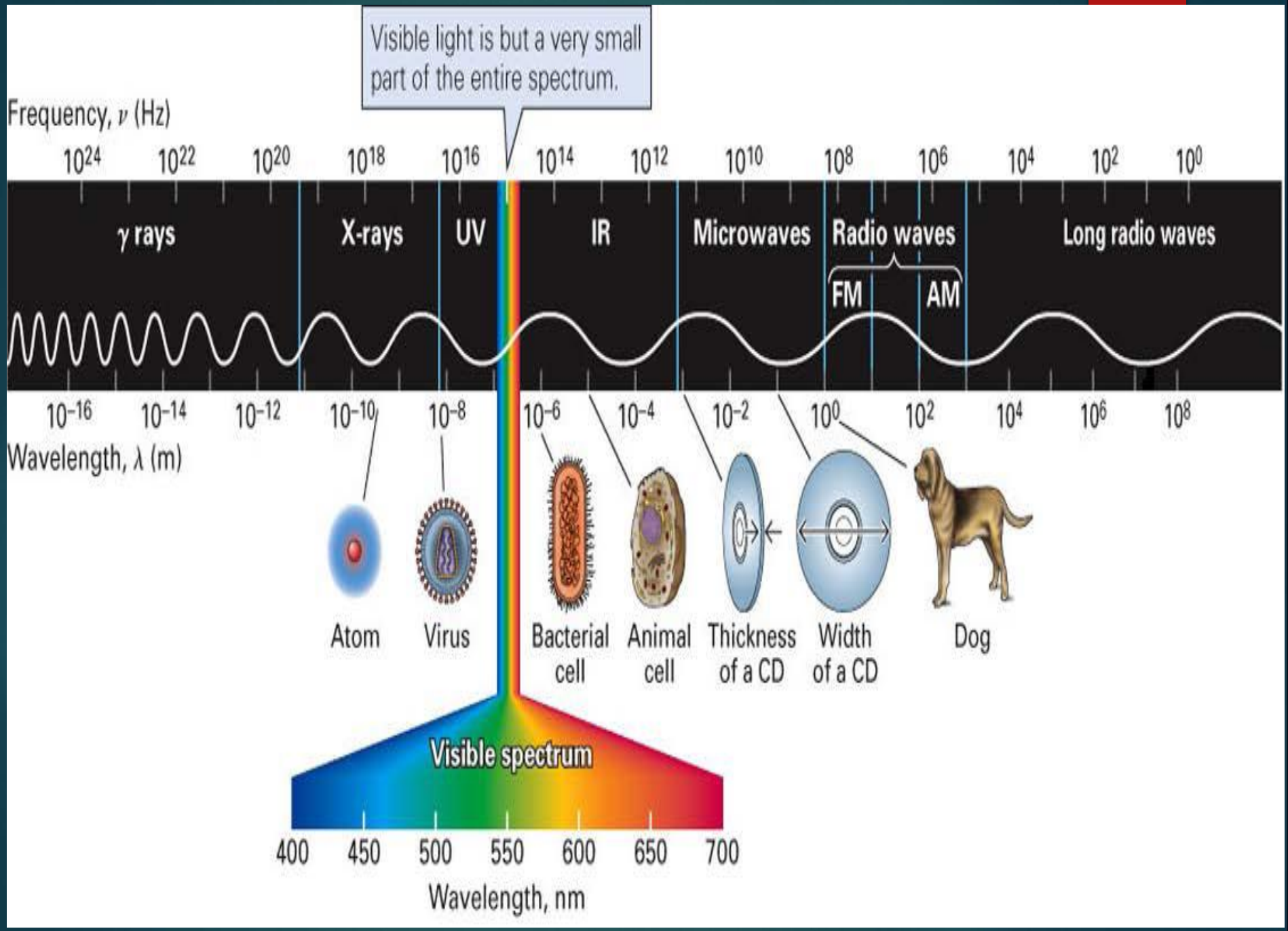


Electromagnetic Radiation

- Electromagnetic radiation is radiant energy that travels through space with wavelike behavior at the speed of light.
- The different forms of electromagnetic radiation are similar in that they all exhibit the same type of wave-like behavior and are propagated through space at the same speed (the speed of light).
- The types of electromagnetic radiation differ in their frequency (and wavelength) and in the resulting amount of energy carried per photon

Electromagnetic Spectrum Cont.,

- Electromagnetic spectrum is a continuum of radiant energy
- The substances below are about the size of the wavelength indicated in the EM spectrum.
- For example, an atom is about 10^{-10}-10^{-9} m in size while a CD is about 10^{-3} m (or 1 mm) thick.


Visible light is but a very small part of the entire spectrum.
Frequency, ν (Hz)
10^24 10^22 10^20 10^18 10^16 10^14 10^12 10^10 10^8 10^6 10^4 10^2 10^0
γ rays
X-rays
UV
IR
Microwaves
Radio waves
FM
AM
Long radio waves
10^-16 10^-14 10^-12 10^-10 10^-8 10^-6 10^-4 10^-2 10^0 10^2 10^4 10^6 10^8
Wavelength, λ (m)
Atom
Virus
Bacterial cell
Animal cell
Thickness of a CD
Width of a CD
Dog
Visible spectrum
400 450 500 550 600 650 700
Wavelength, nm

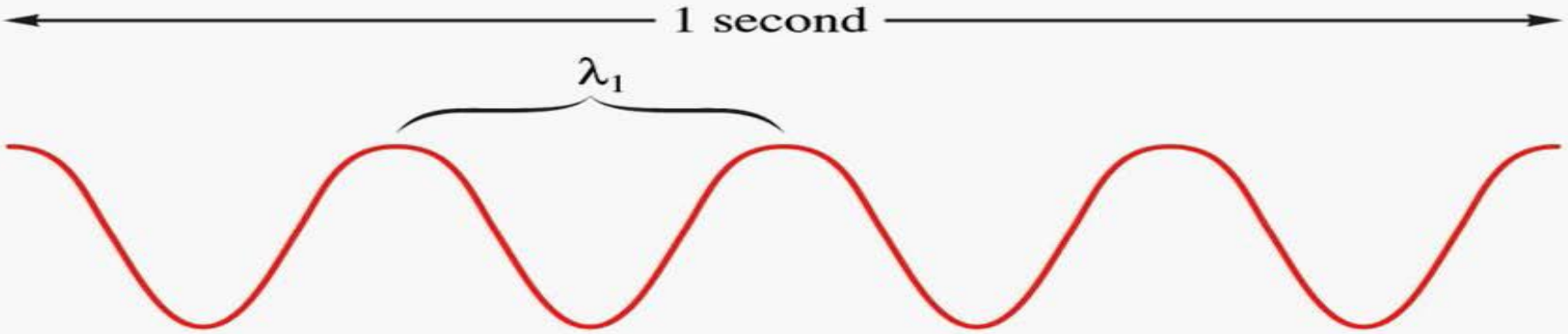
Electromagnetic Spectrum Cont.,

- **Visible region:** Is the portion of the Electromagnetic spectrum that we can perceive as color. For example, a "red-hot" or "white-hot" iron bar freshly removed from a high-temperature source has forms of energy in different parts of the EM spectrum.

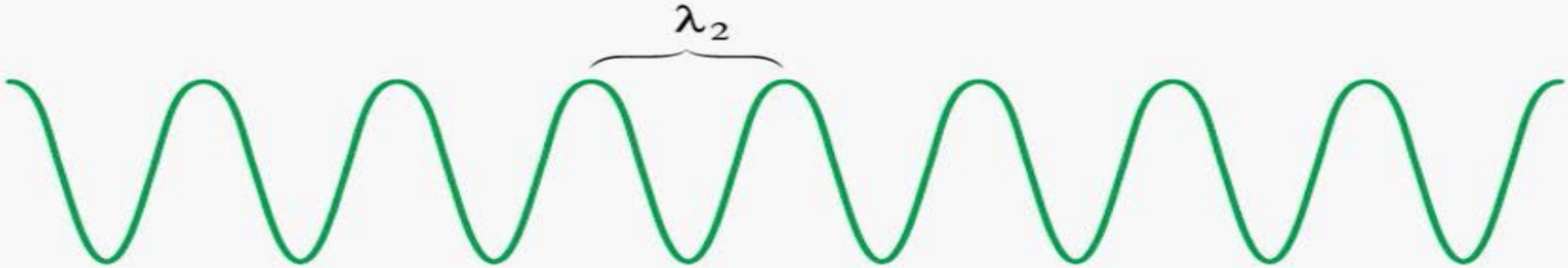
- The red or white glow falls within the visible region, and heat falls within the infrared region.
- **Ultraviolet radiation** is of shorter wavelength than visible light, and therefore is of higher energy than visible light.

Characteristics of Electromagnetic Waves

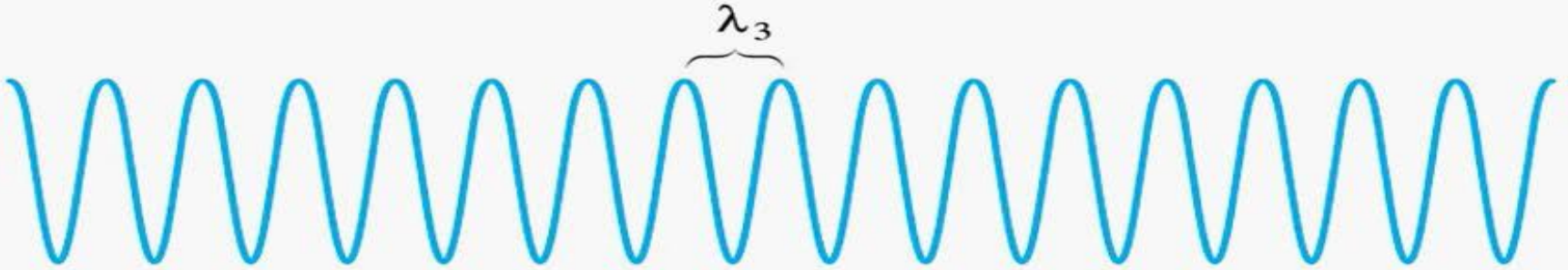
- Electromagnetic waves have both wavelength and frequency
- **Wavelength (λ=Greek "lambda"):** distance between successive peaks
- **Frequency (ν=Greek "nu"):** number of waves passing a given point in 1s
- **How is energy related to wavelength and frequency?**
- As the wavelength ↑, **the frequency ↓, and the energy ↓**
- As the wavelength ↓, **the frequency ↑, and the energy ↑**



$\nu_1 = 4$ cycles/second $= 4$ hertz



$\nu_2 = 8$ cycles/second $= 8$ hertz



$\nu_3 = 16$ cycles/second $= 16$ hertz

Electromagnetic Spectrum Cont.,

- In Electromagnetic spectrum, electromagnetic radiation travels as waves. A particular wave is characterized by three properties: wavelength, frequency, and speed.

- The wavelength represents the distance between corresponding points on two successive waves. The **energy of a photon is inversely proportional to the wavelength**
- **($E = hc/\lambda$)**

- **The speed of electromagnetic radiation represents how fast a given wave moves through space.**
- **The frequency of electromagnetic radiation represents how many complete cycles of the wave pass a given point per second. These two concepts are not the same.**

EMISSION OF ENERGY BY ATOMS

The color display of fireworks results from atoms absorbing energy and becoming excited.

EMISSION OF ENERGY BY ATOMS

- Atoms in an excited state are higher in energy and unstable and when they return to a lower, more stable energy state, they release photons (or light energy), sometimes in the form **of visible light that we can observe as colored light.**

- Different elements give off different energy, which leads to their characteristics colors (e.g. calcium for orange, barium and copper for green, lithium for reddish-pink, etc.).

- The color depend on the arrangement of electrons within each element since elements differ in the numbers of protons and electrons.

The Atoms Elements that Emit Visible Colors Emit Unique Characteristics Colors (flame tests)