Properties of Light

- Energy travels through space in the form of electromagnetic radiation (EMR).
- Examples of types of EMR: radio waves, x-rays, microwaves, visible light. All different types have different energies, wavelengths and frequencies associated with them.
- Figure 7.2.
- All electromagnetic radiation travels in wave motion.

**Question:** What is the difference between wavelength and frequency?

- **Wavelength:**

- **Frequency:**

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**Energy Associated with Electromagnetic Radiation**

- EMR has the properties of waves but transfers energy in a manner similar to particles.
- Only certain quanta or packets of energy can be transferred by the various wavelengths that make up EMR.

**Question:** What are these packets of energy called?

**Answer:**
For any specific wavelength, the energy from that wavelength can be thought of as a stream of tiny particles called photons.
- EMR which was previously thought to exhibit only wave properties, seems to show certain characteristics of particulate matter as well – called wave-particle duality.

**Question:** How is the energy per photon calculated? How are energy and frequency related?
**Answer:**

**Question:** How is energy related to wavelength?
**Answer:**

**Question:** Calculate the frequency and energy of:
(a) UV irradiation where \( \lambda = 1.00 \times 10^{-8} \) m
(b) Microwaves where \( \lambda = 3.00 \) cm

**Answer:**

**Emission Spectra:**
- Figure 7.6
- A sample of \( \text{H}_2 \) receives a high energy spark, \( \text{H}_2 \) molecules absorb energy and some H-H bonds are broken.
- The resulting H atoms are excited, they contain excess energy, which they release by emitting light of various wavelengths to produce an emission spectrum.
- Every element has a unique spectrum – called a fingerprint.

**Question:** What is the significance of the hydrogen emission spectrum?
**Answer:** Explained by the Bohr model.
Bohr Model:

1. Electrons occupy circular orbits about the nucleus.
2. Only certain orbits are allowed (indicated by \( n = 1, 2, 3, \ldots \infty \)).
3. Each orbit has an energy associated with it: \( E_n = -\frac{Z^2 R_H}{n^2} \)
4. Electrons move from one orbit to another by absorbing or emitting photons of light.

\[ \Delta E = E_2 - E_1 = -\frac{Z^2 R_H}{n_2^2} - \frac{1}{n_1^2} \]

*note: \( R_H = 2.178 \times 10^{-18} \text{ J} \)

\( Z = \text{atomic number} \)

Notes about the Bohr Model

- \( n \) represents allowed energy states, called principle quantum number: has values = 1, 2, 3, 4, 5, \ldots \infty.
- \( n = 1 \) is the ground state (lowest energy, electron is closest to nucleus).
- \( n = 2 \) and greater are called excited states.
- \( n = \infty \) means the electron is completely removed from atom.
- As \( n \) increases, the electron is further from the nucleus and has a higher energy.
- **Absorption** – electron moves to a higher energy level, \( \Delta E \) is positive.
- **Emission** – electron moves to a lower energy level, \( \Delta E \) is negative.
- Bohr model only works for one electron systems (H, He\(^+\), etc.)

**Question:** How does the Bohr model explain the emission spectrum of hydrogen?

**Answer:**

**Question:** Why don’t we see more lines in the hydrogen emission spectrum since there are an infinite number of allowed transitions?

**Answer:**
**Question:** The red-orange line in the hydrogen emission spectrum corresponds to the $n=3$ to $n=2$ transition. Are the other transitions in the hydrogen emission spectrum of higher or lower energy?

**Answer:**

**Question:** Each atom/ion has its own unique emission spectrum. Why?

**Answer:**

**Question:** From experiment the red-orange line in the hydrogen emission spectrum has a wavelength of 657 nm. This line corresponds to the $n_1 = 3$ to $n_2 = 2$ electronic transition. Use the Rydberg equation to calculate the wavelength of the red-orange line.

**Answer:**

- The minus sign in the answer show that this is an emission (a loss of energy by the atom). This energy value exactly equals the energy of the photon of light emitted. The energy of a photon is always a **positive** value.

**Ionization Energy:** the energy required to completely remove an electron from the ground state ($n_1 = 1$ to $n_2 = \infty$). Calculate the ionization energy of hydrogen.

**Answer:**
Question: Calculate the ionization energy for Li$^{2+}$.
Answer:

- The Bohr model does not work for atoms/ions that contain more than one electron. This is the vast majority of atoms/ions.