Section 10: Light

The following maps the videos in this section to the Texas Essential Knowledge and Skills for Science TAC §112.35(c).

10.01 Wave Nature of Light
- Chemistry (6)(B)
- Chemistry (6)(C)

10.02 Particle Nature of Light
- Chemistry (6)(B)
- Chemistry (6)(C)

Note: Unless stated otherwise, any sample data is fictitious and used solely for the purpose of instruction.

10.01

Wave Nature of Light

Visible light is just one of many forms of ***electromagnetic radiation***. All electromagnetic radiation consists of radiant energy. We can study electromagnetic radiation from two different perspectives: as a ***wave*** or as a series of ***particles***.

Wave Properties of Light

The wave properties of electromagnetic radiation can be described by the following interdependent variables:

- ***Frequency (v)* –** the number of wave cycles that pass a given point per second, expressed in units of **inverse seconds (s^{-1})** or **Hertz (Hz)**
- ***Wavelength (λ)* –** the distance between identical points on two neighboring waves, expressed in units of **meters (m)**
    - Consider wavelength as the distance the wave travels during one cycle.
    - Wavelength can also be expressed in **nanometers (nm)**, **picometers (pm)**, or **Angstroms (Å)**.

        Note: 1 meter = 1×10^{10} Å
- ***Amplitude*** – the distance from the middle of a wave to its crest

    The amplitude of a wave is a measure of the wave's intensity.

The following equation relates the frequency and wavelength of any form of electromagnetic radiation:

$$c = v * \lambda$$

In the equation above, *c* is a constant that represents the ***speed of light*** in a vacuum, which is approximately 3.00×10^{8} meters per second.

Electromagnetic Spectrum

The ***electromagnetic spectrum*** displays different waves of electromagnetic radiation. Waves in the electromagnetic spectrum travel at the same speed through a vacuum, but they differ in frequency and wavelength.

Electromagnetic Spectrum						
10^{20} Hz	10^{18} Hz	10^{16} Hz	10^{15} Hz	10^{13} Hz	10^{11} Hz	10^{8} Hz
γ–ray	X–ray	UV	VIBGYOR	IR	Microwave	Radio Waves
10^{-2} nm	10^{0} nm	10^{2} nm	380–700 nm	10^{4} nm	10^{7} nm	10^{10} nm

STUDY EDGE TIP

In the visible light range, the wavelengths vary from **380 nm (violet) to 700 nm (red)**. We can use the spectrum above to show that green light has a shorter wavelength than red light.

1. What is the frequency of electromagnetic radiation that has a wavelength of 1059 nm?

    A. 6.548×10^{11} Hz
    B. 2.833×10^{14} Hz
    C. 7.127×10^{14} Hz
    D. 6.548×10^{11} Hz

10.02

Particle Nature of Light

As an object is heated, the visible light it emits changes color from red to light blue, and eventually, to white. A German physicist, ***Max Planck***, developed a theory to explain this phenomenon in the early 1900s.

Planck asserted that a heated object could emit or absorb only fixed, discrete quantities of energy, called ***quanta*** (singular: ***quantum***).

In the 1880s, the work of another German physicist, ***Heinrich Hertz,*** led to the discovery of a phenomenon called the ***photoelectric effect***. The photoelectric effect occurs when light of a sufficient frequency shines on a metal surface and causes an electric current to flow.

- The ***threshold frequency*** is the minimum frequency required to generate a current in a given metal. When the light reaches the threshold frequency, it has enough energy to eject an electron from the surface of the metal, generating a current.
- There is no time lag when the minimum frequency is reached, so the current begins instantaneously.

Building on Planck's idea, ***Albert Einstein*** proposed that light itself is particulate in nature, consisting of tiny "bundles" of energy called ***photons***. These photons can be thought of as particles of light, which can be described by the following equations:

$$\Delta E_{atom} = E_{photon} = h * \upsilon = \frac{h * c}{\lambda}$$

In the equations above, *h* is Planck's constant (6.626×10^{-34} J · s), *E* is the energy of the radiation ($\frac{J}{photon}$), *v* is the frequency of the radiation (s^{-1} or Hz), *c* is the speed of light in a vacuum (3.00×10^{8} m/s), and λ is the wavelength of the radiation (m).

1. The lowest frequency of light that will produce the photoelectric effect is called the "threshold frequency." The threshold frequency for sodium is 5.5×10^{14} Hz. Which of the following values is closest to the energy of a photon of this frequency?

   A. 8.63×10^{-19} J
   B. 7.48×10^{-18} J
   C. 6.10×10^{-19} J
   D. 3.64×10^{-19} J

2. What is the energy, in J, of 100 photons of light, each having a wavelength of 355 angstroms?