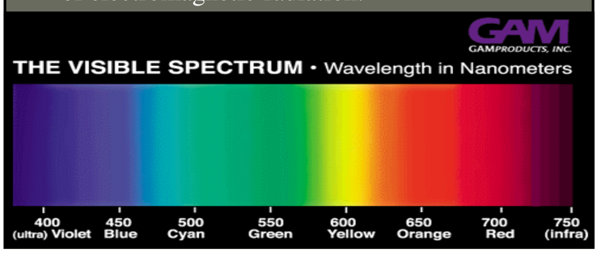
SECTION 4-1 REVIEW

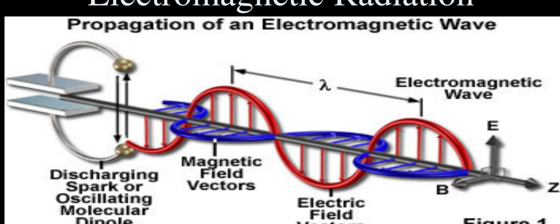
The Development of A New Atomic Model

Properties of Light

- Light properties can both be described in terms of particles or as waves. Visible light is a kind of electromagnetic radiation.



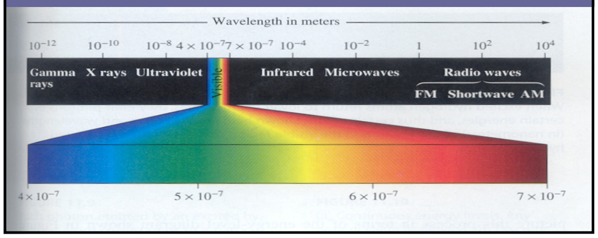
Electromagnetic Radiation



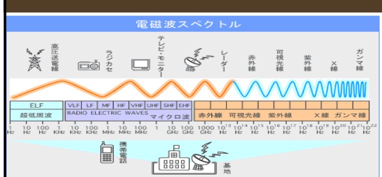
- A form of energy which exhibits wavelike behavior as it travels through space. Includes X-rays, ultraviolet and infrared light, microwaves, and radio waves. See p. 92.

Electromagnetic Spectrum

- All the forms of electromagnetic radiation taken together. They all move at the speed of light (*c*) in a vacuum. See p. 92 for diagram.
- $c = 3.00 \times 10^8$ m/s



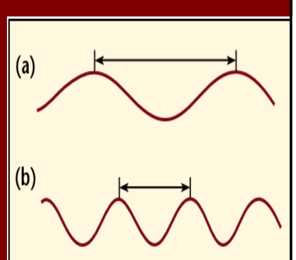
Waves Are Periodic



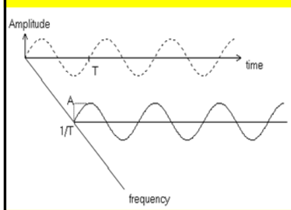
- That is they are of a repetitive nature, and can be characterized by the measurable properties of wavelength and frequency.

Wavelength

- Symbol: λ (lambda)
- The distance between corresponding points on adjacent waves.
- Depending on the wave, can be expressed in the units m, cm, or nm.



Frequency



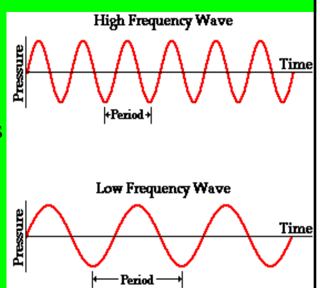
- Symbol: ν (nu)
- The number of waves that pass a given point in a specific time, usually one second.
- Units are Hertz
- 1 wave/s = 1 Hz

Inversely Related

- For <u>all</u> electromagnetic radiation:

$$c = \lambda\nu$$

Since the speed of light is a constant, as λ increases ν <u>must</u> decrease, and verse visa.



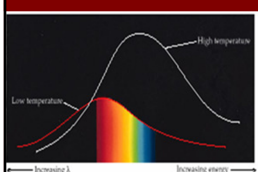
Practice Problem #1

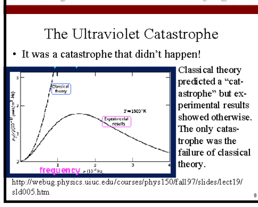
- Indigo-colored light has a wavelength of approximately 440 nm. What is the frequency of this light?

Mystery of the Photoelectric Effect

- For a given metal, no electrons were emitted if the light's frequency was below a certain minimum, no matter how long the light shone.
- Wave theory predicted that light of ANY frequency could supply enough energy to the metal to knock an electron loose from a metal.
- So scientists couldn't explain why the light had to be of a minimum frequency in order for the photoelectric effect to occur. They had to come up with a new idea.

Max Planck -- 1900





- Max was studying light emitted by hot objects. He suggested that the electro-magnetic energy was emitted not in a continuous wave, ***but in discrete packets like a particle.***
- **These small, specific amounts of energy are called *quanta.***

According to Planck, a **quantum** is the minimum quantity of energy that can be lost or gained by an atom.

Max proposed a relationship between a quantum of energy and the frequency of electromagnetic radiation:

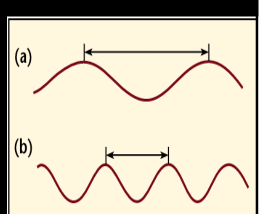
$$E = h\nu = hc / \lambda$$

E is energy in joules of a quantum of radiation.

ν is the frequency of the emitted radiation.

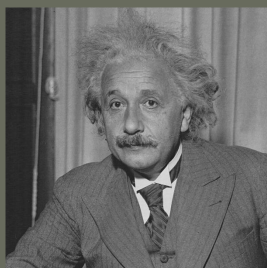
h is **Planck's constant** =

6.626×10^{-34} J•s



Which has the higher energy, a or b?

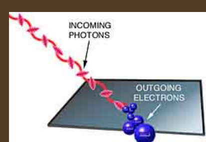
1905 – Einstein expands the theory by introducing idea of wave-particle duality of light



Einstein called the light particles **photons**. A photon is a particle of electromagnetic radiation having zero rest mass and carrying a quantum of energy such that

$$E_{photon} = h\nu = hc / \lambda$$

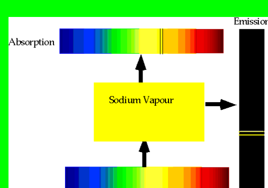
Al's explanation of the Photoelectric Effect



- Electromagnetic radiation is absorbed by matter only in whole numbers of photons.
- For an electron to be ejected from a metal surface, the electron must be struck by a single photon possessing at least the minimum energy required to knock the electron loose. This corresponds to a minimum radiation frequency.
- Electrons in different elements are bound to the nucleus more or less tightly, so different metals require different minimum frequencies to exhibit the photoelectric effect.

Practice Problem #2

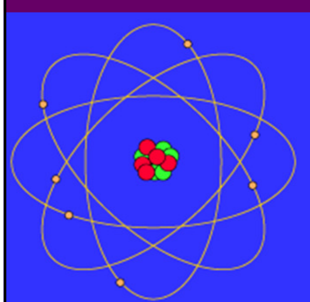
- Sodium emits yellow light with a wavelength of approximately 570 nm. What is the frequency of this radiation in Hz?



Practice Problem #3

- Helium emits light at 420 nm. What is the energy of a single photon of this radiation in joules?

Bohr's Model of the Atom

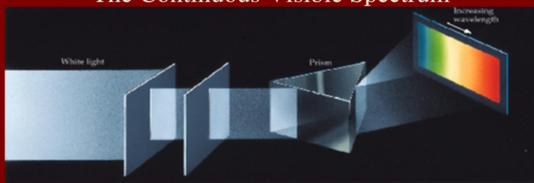


- The electron can circle the nucleus only in allowed paths, or *orbits.* Each orbit has a definite, fixed energy.
- The energy of the electron is higher when it is in orbits that are successfully farther from the nucleus.
- An electron can be in one orbit or another, but not in between.
- While in an orbit the electron can neither gain nor lose energy.

Different Energy States

- When electric current is passed through a gas at low pressure, the potential energy of some of the gas atoms increases.
- The lowest energy state of an atom is its **ground state.**
- A state in which an atom has a higher potential energy than it has in its ground state is an **excited state.**

The Continuous Visible Spectrum



When white light is passed through a prism, the visible spectrum becomes apparent as a continuous series of electromagnetic waves covering a wide range of wavelengths and frequencies.

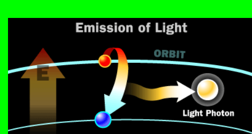
But Not For All Light

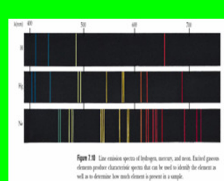
Figure 7.9 The line emission spectrum of excited hydrogen atoms. The emitted light is passed through a series of slits to isolate a narrow beam of light, which is then separated into its component wavelengths by a prism. A photographic plate or an instrument detects the separate wavelengths as individual lines. Hence, the name "line spectrum" for the light emitted by a glowing gas.

When scientists passed electric current through a vacuum tube containing hydrogen gas at low pressure, they observed a characteristic pink glow. When a narrow beam of the emitted light was shone through a prism, it was separated into a series of specific frequencies (and hence energies). This is known as hydrogen's *light emission spectrum.*

Different Elements, Different Spectra

Each element has an identifying color it gives off when its electrons are excited by absorbing energy. The electrons absorb energy in the form of heat or light, causing them to jump to higher energy levels. They are unstable here, so they fall back to ground state and give off a color of light that matches the energy different between the two energy levels jumped. This creates an element's SPECTRA





Proof of the Big Bang & Space Exploration

- The shifting of spectral lines shows that distant galaxies are receding relative to our own.
- We also use spectra to identify the elements that make up stars and planets in distant space

But Problems Still Lurked Outside Hydrogen

- Bohr's success in explaining mathematically the spectral lines of hydrogen did not work when trying to explain the spectra of atoms with more than one electron.
- Nor did Bohr's theory fully explain the chemical behavior of atoms.
- A better (and *stranger*) idea was needed.