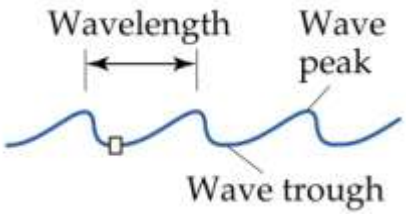
# Origins of Quantum Theory and the Bohr Model of the Atom

Chapter 3.3 and 3.4

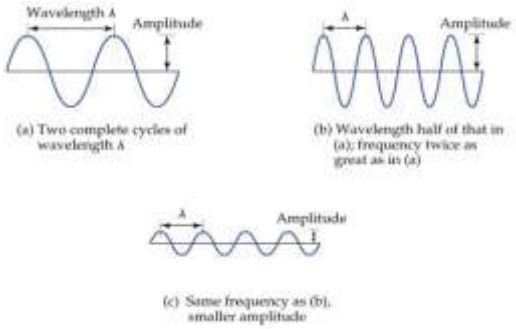
## The Study of Light

- Why do we study the nature of light in a chemistry class?
- Much of what we know about the electronic structure of atoms comes from the interaction of the atoms with light.
- By *light*, a chemist means *all* electromagnetic radiation.
  - *Visible light*, the light that is detected by our eyes, is only a small portion of the EM spectrum.
  - More energetic light includes ultraviolet, X-rays, and gamma rays.
  - Less energetic light includes infrared, microwaves, radio waves

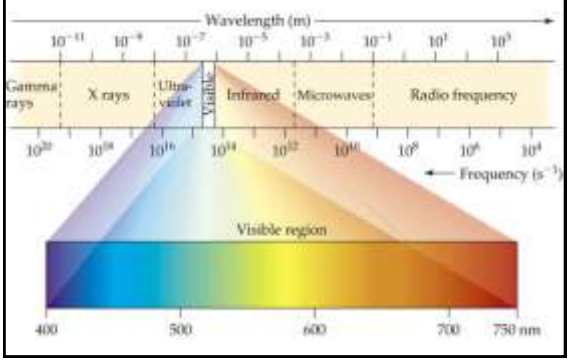
## The Wave Nature of Water




## The Wave Nature of Light




## The Wave Nature of Light




## Quantum Hypothesis

- Maxwell Planck (1858-1947) showed that light could only be emitted in "packets," known as photons, not as a continuous wave. (Nobel prize, 1918)

## The Wave Nature of Light

TABLE 6.1 Common Wavelength Units for Electromagnetic Radiation

| Unit | Symbol | Length (m) | Type of Radiation |
|---|---|---|---|
| Angstrom | Å | $10^{-10}$ | X ray |
| Nanometer | nm | $10^{-9}$ | Ultraviolet, visible |
| Micrometer | μm | $10^{-6}$ | Infrared |
| Millimeter | mm | $10^{-3}$ | Infrared |
| Centimeter | cm | $10^{-2}$ | Microwave |
| Meter | m | 1 | TV, radio |

## Quantized Energy and Photons

- Planck gave the name quanta to the smallest quantity of energy of a given wavelength that can be absorbed or emitted by an atom.
- To understand quantization consider walking up a ramp versus walking up stairs:
- For the ramp, there is a continuous change in height whereas on stairs, there is a quantized change in height.

## Max Planck's Hypothesis

- Proposed that the exchange of energy between matter and radiation occurs in quanta, or packets of energy
- Planck came up with $E = h\nu$ to explain the observational data
- E=energy
- h=6.626 x $10^{-34}$ *Planck's constant*
- $\nu$=frequency (frequency is also written as $f$)

## Photoelectric Effect

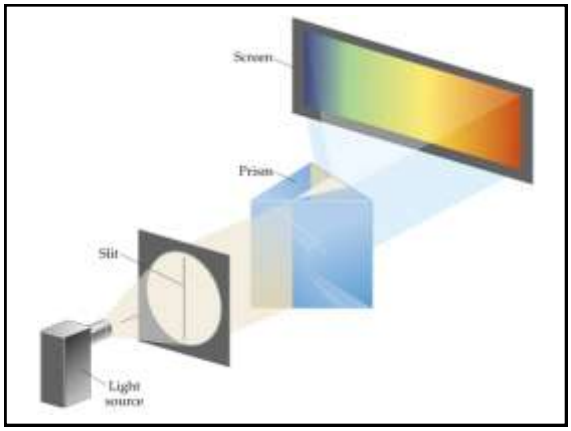

## Photoelectric effect:

**(Explained in terms of photons)**

- An electron can be driven out of the metal only if it receives at least a certain minimum energy from the photon during the collision. Frequency of radiation must have a certain minimum value for electrons to be ejected
- Provided a photon has enough energy, a collision results in the immediate ejection of an electron

## Line Spectra and the Bohr Model

- Radiation composed of only one wavelength is called monochromatic.
- Radiation from most common sources spans an array of different wavelengths, and is called continuous.
- If white light is passed through a prism, it is separated into a continuous spectrum of colors.
- Notice that there are no dark spots on the continuous spectrum.



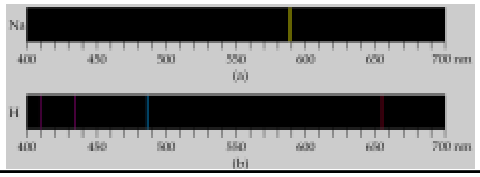

## Line Spectra and the Bohr Model

Not all radiation sources emit a continuous spectrum.

- When gases are placed in a tube under reduced pressure and a high voltage is applied, light is emitted only in certain colors.
  - sodium vapor – yellow
  - neon – orange-red

## Line Spectra and the Bohr Model

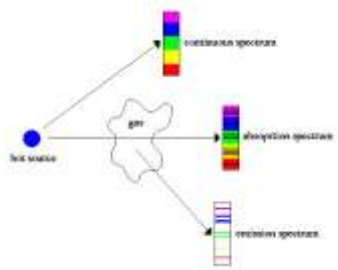
- When this light is passed through a prism, only narrow bands are present, separated by black regions.
  - These black regions correspond to wavelengths that are not present in the light.
  - These are called line spectra.



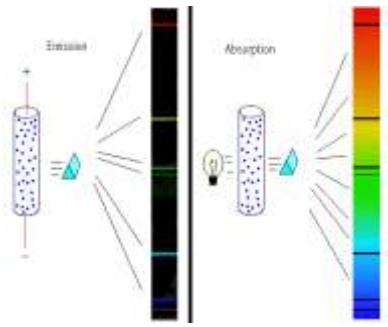

## Spectra

Three types:

- Continuous
- Emission
- Absorption



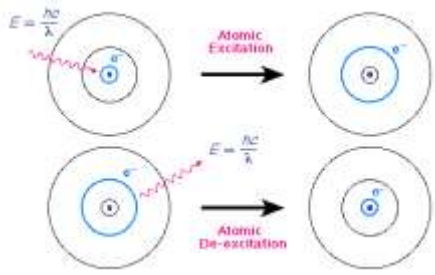
## Spectra




## Niels Bohr

- In 1913 proposed a model to explain spectra of hydrogen.
  - Simple planetary model
  - Electrons can exist only in specific orbits (called quantized states).
  - When the electron is in an allowed orbit, it does not radiate energy. It is stable. Stable orbits are called *ground states*.
  - Atom **emits** energy (gives off a photon) only when moving from high energy state to another.
  - Atom **absorbs** energy (captures a photon) when moving from low to high (excited) energy levels.

## Bohr Hydrogen Atom




## Line Spectra and the Bohr Model

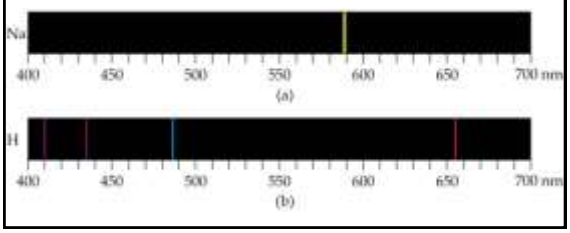
**Bohr Model**

- Bohr's model incorporated three postulates:
  1. Only orbits of certain radii are allowed. These radii correspond to specific energies.
  2. An electron in a permitted orbit has this specific energy, an "allowed" energy state. Electrons will not radiate energy, into a state that is not "allowed", so will not spiral into the nucleus.
  3. Energy is only emitted or absorbed by an electron as it moves from one "allowed" state to another. This energy is emitted or absorbed as a photon, $E = h\nu$.

## Line Spectra and the Bohr Model

**Bohr Model**

- Because the electrons are moving from one specific state to another, only specific photons are emitted.




## Line Spectra and the Bohr Model

**Limitations of the Bohr Model**

- The Bohr model can only explain the line spectrum of hydrogen adequately.
- Electrons can not be completely described as small particles.