School of Basic and Applied Sciences

Course Code : BCHY2008 Course Name: Analytical Chemistry 1

Quantum theory of electromagnetic radiations

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Quantum Theory

- 1900 - Max Planck
- Radiant energy could only be emitted or absorbed in discrete quantities
- Quantum: packets of energy
- Correlated data from blackbody experiment to his quantum theory
- Revolutionized way of thinking (energy is quantized)

Quantum Theory

- Energy of a single quantum of energy

$$E = h\upsilon$$

where

E = energy (in Joules)

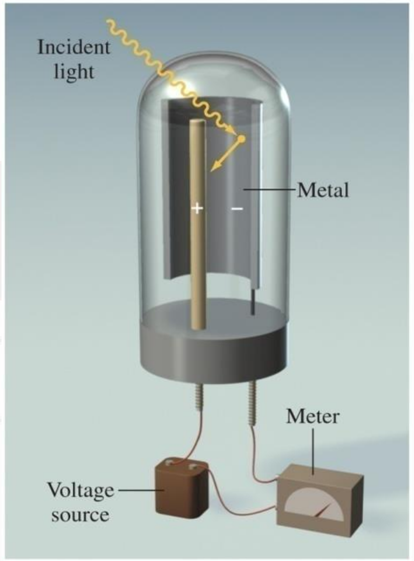
h = Planck's constant 6.63×10^{-34} J · s

ν = frequency

Photoelectric Effect

- Electrons ejected from a metal's surface when exposed to light of certain frequency
- Einstein proposed that particles of light are really **photons** (packets of light energy) and deduced that

$$E_{\text{photon}} = h\nu$$



- Only light with a frequency of photons such that $h\nu$ equals the energy that binds the electrons in the metal is sufficiently energetic to eject electrons.
- If light of higher frequency is used, electrons will be ejected and will leave the metal with additional kinetic energy.
    - (what is the relationship between energy and frequency?)
- Light of at least the threshold frequency **and** of greater *intensity* will eject *more* electrons.

Calculate the energy (in joules) of a photon with a wavelength of 700.0 nm

$$\lambda = 700.0\,\text{nm} \times \frac{10^{-9}\,\text{m}}{\text{nm}} = 7.00\times10^{-7}\,\text{m}$$

$$\upsilon = \frac{3.00\times10^{8}\,\text{m/s}}{7.00\times10^{-7}\,\text{m}} = 4.29\times10^{14}\,\text{s}^{-1}$$

$$E = (6.63\times10^{-34}\,\text{J}\cdot\text{s})(4.29\times10^{14}\,\text{s}^{-1})$$

$$E = 2.84\times10^{-19}\,\text{J}$$

Calculate the wavelength (in nm) of light with energy 7.83 x 10^{-19} J per photon. In what region of the electromagnetic radiation does this light fall?

$$\upsilon = \frac{7.83\times10^{-19}\,\mathrm{J}}{6.63\times10^{-34}\,\mathrm{J\cdot s}} = 1.18\times10^{15}\,\mathrm{s}^{-1}$$

$$\lambda = \frac{3.00\times10^{8}\,\mathrm{m\cdot s^{-1}}}{1.18\times10^{15}\,\mathrm{s}^{-1}} = 2.53\times10^{-7}\,\mathrm{m} \quad \mathrm{or}\ 253\,\mathrm{nm}$$

Ultraviolet region

Photoelectric Effect

- Dilemma caused by this theory - is light a wave or particle?
- Conclusion: Light must have particle characteristics as well as wave characteristics

Black-body radiation

- Black-body radiation has a characteristic, continuous frequency spectrum that depends only on the body's temperature, called the Planck spectrum or Planck's law.
- The spectrum is peaked at a characteristic frequency that shifts to higher frequencies with increasing temperature, and at room temperature most of the emission is in the infrared region of the electromagnetic spectrum.
- As the temperature increases past about 500 degrees Celsius, black bodies start to emit significant amounts of visible light. Viewed in the dark by the human eye, the first faint glow appears as a "ghostly" grey (the visible light is actually red, but low intensity light activates only the eye's grey-level sensors). With rising temperature, the glow becomes visible even when there is some background surrounding light: first as a dull red, then yellow, and eventually a "dazzling bluish-white" as the temperature rises.
- When the body appears white, it is emitting a substantial fraction of its energy as ultraviolet radiation. The Sun, with an effective temperature of approximately 5800 K, is an approximate black body with an emission spectrum peaked in the central, yellow-green part of the visible spectrum, but with significant power in the ultraviolet as well.

References:

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