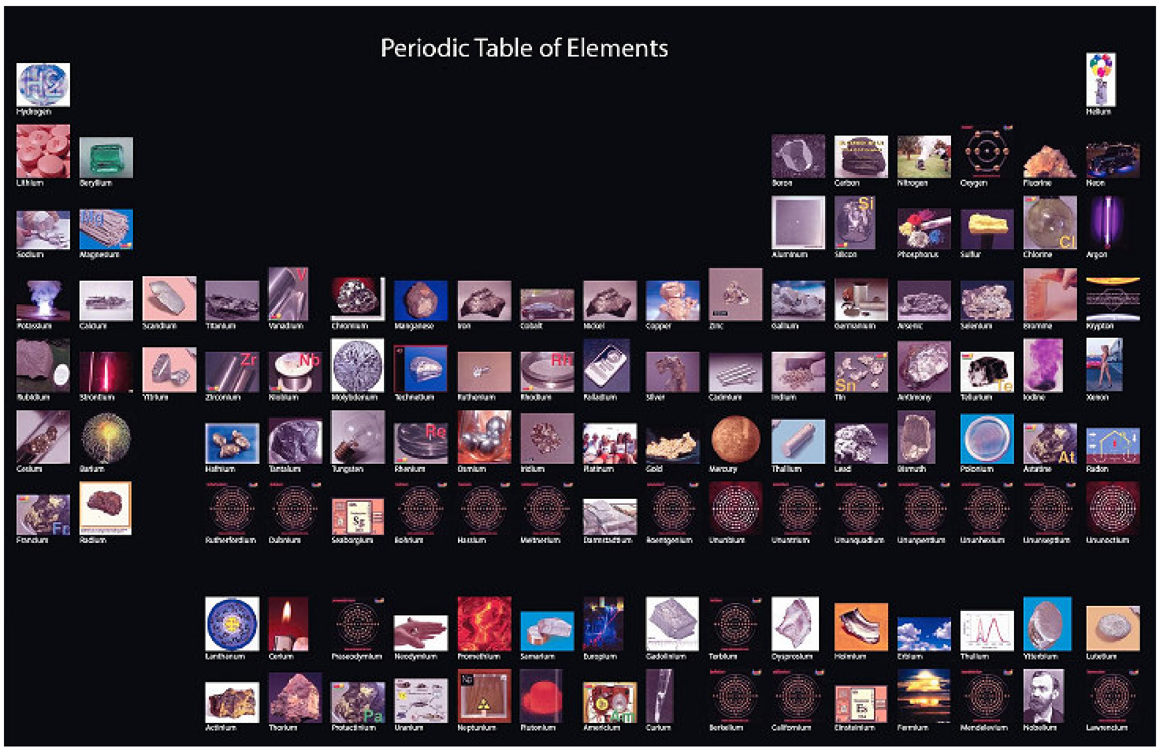
University Chemistry
Dr. Mohamed A. Salam

Chapter 4

The Electronic Structure

&

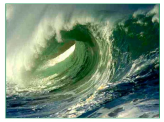
the Periodic Table

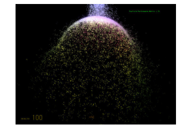


University Chemistry

Electromagnetic Radiation

- Electromagnetic radiation has some of the properties of both a **particle** and a **wave**.

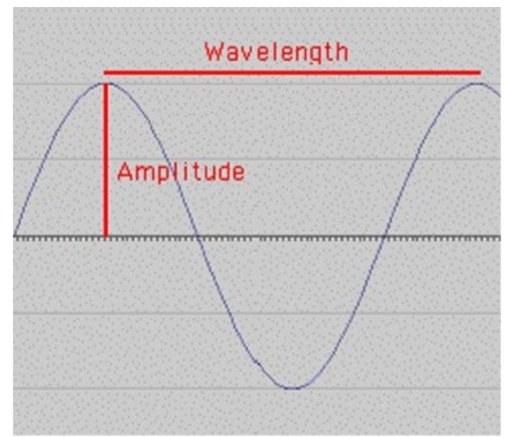




- ***Particles:*** *have a* definite **mass** and they occupy space.

- ***Wave*** have **no mass** and yet they carry **energy** as they travel through space.

Waves have four other characteristic properties: speed, frequency, wavelength, and amplitude.

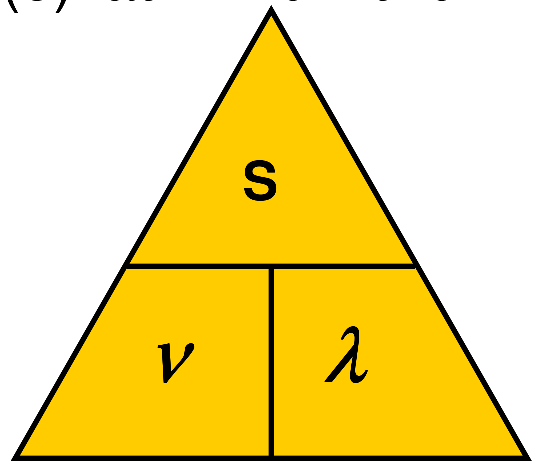


The **frequency** (*v*) is the number of waves (or cycles) per unit of time and its units of cycles per second (s-1) or hertz (Hz).

The **wavelength** (*l*) is the smallest distance between repeating points on the wave. The product of the frequency (*v*) times the wavelength (*l*) of a wave is therefore the speed (*s*) at which the wave travels through space.

The product of the frequency (ν) times the wavelength (λ) of a wave is therefore the speed (s) at which the wave travels through space.

$$s = \nu\lambda \quad \text{or} \quad \nu = s/\lambda$$

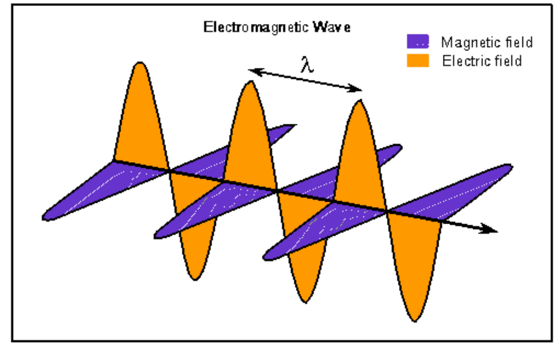


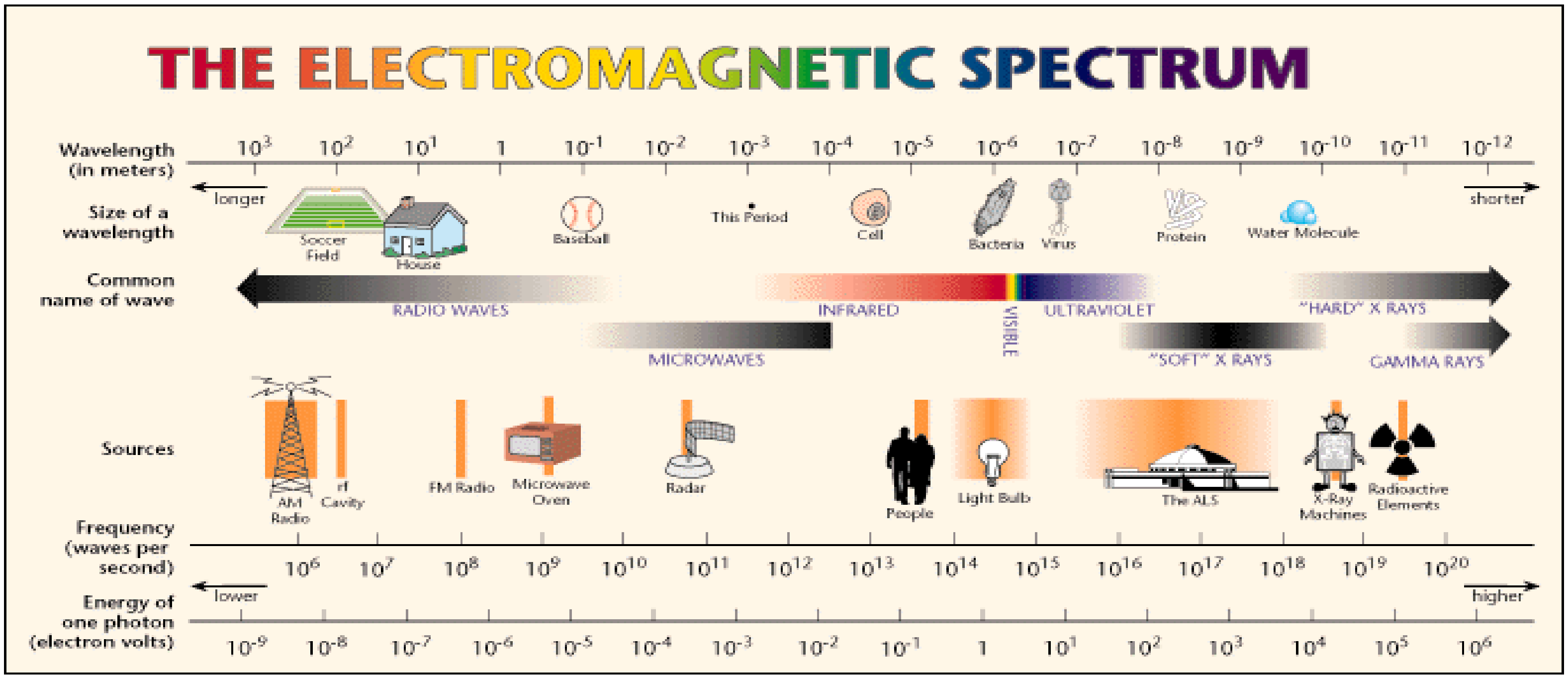
What is the speed of a wave that has a wavelength of 1 meter and a frequency of 60 cycles per second?

λ = 1 m and ν = 60 cycles per second (Hz)

$s = \nu\lambda$ = 60 (Hz) x 1 m = 60 m per second

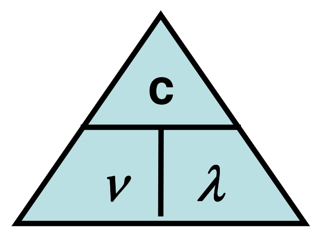
- Light is a wave with both *electric* and *magnetic* components. It is therefore a form of **electromagnetic radiation**.





The product of the frequency times the wavelength of electromagnetic radiation is always equal to the speed of light (c), 3.00×10^8 m/s.

$$c = \nu\lambda \quad or \quad \nu = c/\lambda$$



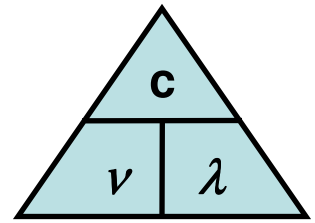
Calculate the frequency of red light that has a wavelength of 700.0 nm if the speed of light is 3.00 x 10^8 m/s.

λ = 700.0 nm = 700.0 x 10^{-9} m and c = 3.00 x 10^8 m/s

$c = \nu\lambda$ or $\nu = c / \lambda$

ν = 3.00 x 10^8 (m/s) / 700.0 x 10^{-9} (m)

ν = 4.29 x 10^{14} (s^{-1}) or Hz

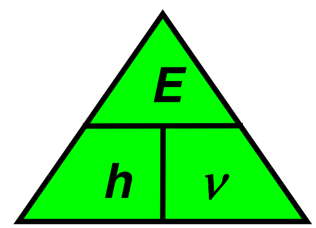


Ephoton = h v

Particle-Like Behavior of Light and Planck's Equation

Light is composed of particles called photons.
The energy of this photon is equal to the frequency of the light times a constant and can be calculated using the formula:

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



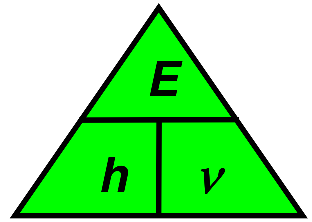
where E is the energy of the photon, ν is the frequency and h is called Plank's constant, $h = 6.63 \times 10^{-34}$ J s

What is the energy (in kilojoules) of photons of radar waves with a frequency equal 4.00×10^{8} Hz?

Using the formula $E_{photon} = h\,\nu$

$E = (6.63 \times 10^{-34}\ \text{J s}) \times (4.00 \times 10^{8}\ \text{s}^{-1})$

$= 2.65 \times 10^{-25}\ \text{J} = 2.65 \times 10^{-28}\ \text{kJ}$



What is the wavelength, in nanometers, of light that has an energy content of 508 kJ/mol photons?

$$\text{Energy} = 508\ \text{kJ/mol photons} \times \left(\frac{1000\text{J}}{1\text{kJ}}\right) \times \left(\frac{1\text{mole photon}}{6.023\times10^{23}\ \text{photons}}\right) = 8.44 \times 10^{-19}\ \text{J/photon}$$

$$E = h\nu = h\,c/\lambda \qquad \lambda = hc/E \qquad \lambda = \left(\frac{(6.626\times10^{-34}\ \text{J}\bullet\text{s})(3.00\times10^{8}\ \frac{\text{m}}{\text{s}})}{8.44 \times 10^{-19}\ \text{J}}\right) = 236 \times 10^{-9}\ \text{m}$$

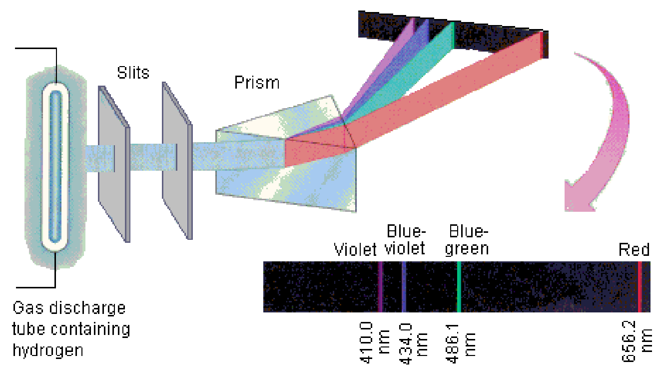
$$\lambda = 236 \times 10^{-9}\ \text{m} = 236 \times 10^{-9} \times 10^{9}\ \text{nm} = 236\ \text{nm}$$

Development of Current Atomic Theory

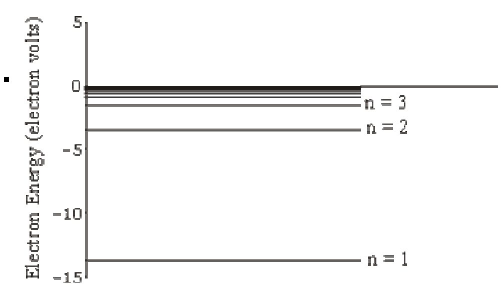
- Atomic spectrum can be used as a "fingerprint" for an element and the scientists conclude that if atoms emit only discrete wavelengths, may be atoms can have only discrete energies.
- The discrete amounts of energy are absorbed or released (energy is said to be quantized).
- Atoms absorb and emit electromagnetic radiation as the energies of their electrons change.

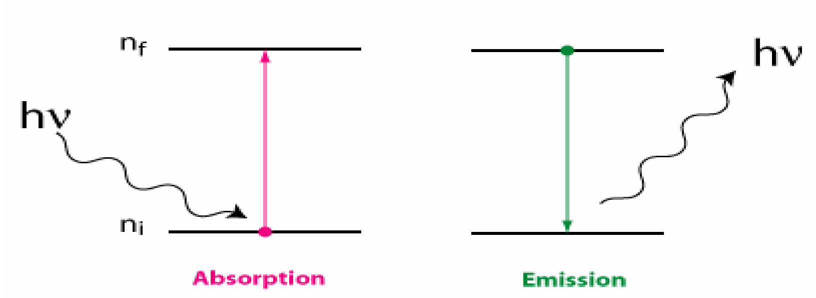
In the case of hydrogen atom spectra, the energies that the electron can possess are given by:

$$E_n = -R_H\,(1/n^2)$$



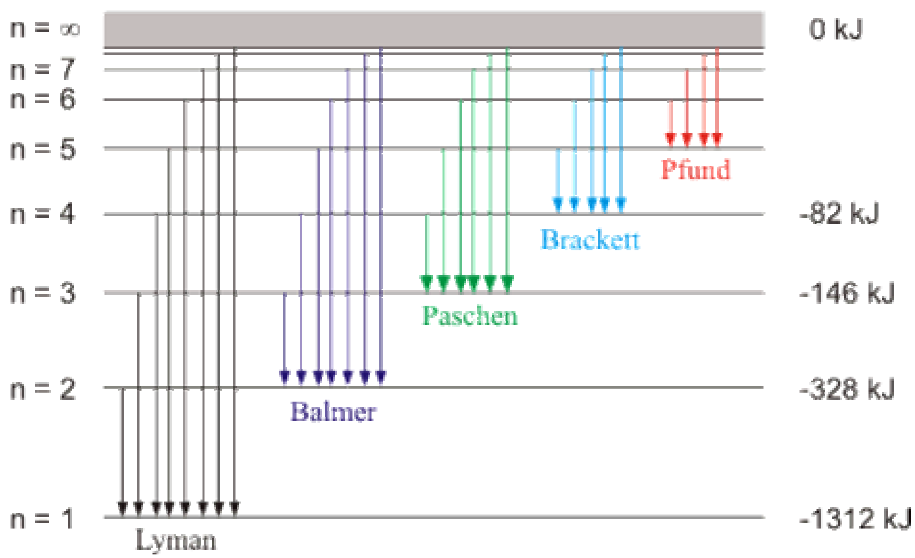
where R_H, the Rydberg constant, has the value 2.18×10^{-18} J. The number n is the integer called the principal quantum number; it has the values n = 1, 2, 3, 4,…





$$E_i = -R_H\,(1/n_i^2) \qquad E_f = -R_H\,(1/n_f^2)$$

$$\Delta E = h\nu = E_f - E_i = R_H\,(1/n_i^2 - 1/n_{f2})$$



Lyman series is due to the transfer of electrons from excited state to ***n*** **=1**

Balmer series is due to the transfer of electrons from excited state to ***n*** **=2**

Paschen series is due to the transfer of electrons from excited state to ***n*** **=3**

Brackett series is due to the transfer of electrons from excited state to ***n*** **=4**

Pfund series is due to the transfer of electrons from excited state to ***n*** **=5**

What is the wavelength of a photon (in nanometers) emitted during a transition from the ni = 5 state to the nf = 1 state in the hydrogen atom?

Step 1: Calculate ΔE using the following equation:

$$\Delta E = hv = E_f - E_i = R_H\,(1/n_i^2 - 1/n_f^2)$$
$$= 2.18 \times 10^{-18}\ \text{J}\ (1/5^2 - 1/1^2)$$
$$= -2.09 \times 10^{-18}\ \text{J}$$

The negative sign (-ve) indicates that this energy associated with an emission process.

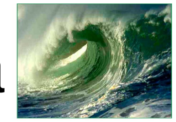
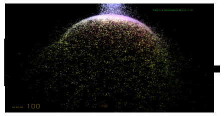
Step 2: calculate the wavelength, (omit the –ve sign of ΔE).

$\Delta E = 2.09 \times 10^{-18}$ J $= hv = h \times c/\lambda$

$\lambda = c\,h/\Delta E = (3.00 \times 10^8\ \text{m/s})\ (6.63 \times 10^{-34}\ \text{J.s}) / (2.09 \times 10^{-18}\ \text{J})$

Wavelength $\lambda = 9.52 \times 10^{-8}$ m $= 9.52 \times 10^{-8} \times 10^9$ nm $= 94.2$ nm

Duality of the Electron

- Electron can be described as if it were a  and 
- Since waves are described by their wavelength λ and particles are described by their momentum, **p,**
- $E = h\nu = hc/\lambda$ (wave)
- $E = mc^2 = pc$ (particle)

The DeBroglie relationship:between **momentum** (a particle property) and **wavelength** (a wave property)

$$p = mc = h/\lambda \quad \text{or} \quad ms = h/\lambda$$

$$\boxed{\mathbf{ms = h/\lambda}}$$

(m is the mass in kg and s is the speed in m/s),

What is the DeBroglie wavelength (in meter) of an electron of a mass 9.11×10^{-31} kg and a speed of 2.2×10^{6} m/s. (Notice that: $J.s = kg.m^2.s^{-1}$)

- Using the formula:

$$m\,s = h/\lambda \text{ or } \lambda = h/m\,s$$

$\lambda = h/m\,s = (6.63 \times 10^{-34}\ kg.m^2.s^{-1})/(9.11 \times 10^{-31} \times 2.2 \times 10^{6}\ m\ s^{-1})$

$= 3.3 \times 10^{-10}$ m

Calculate the energy (in joules) of a photon with a wavelength of 6.00×10^{4} nm.

Using the following formula:

$E_{photon} = h\,\nu$ and $\nu = c/\lambda$

Wavelength (λ) = 6.00×10^{4} nm

$= 6.00 \times 10^{4} \times 10^{-9}\ m = 6.00 \times 10^{-5}$ m,

Speed of light (c) = 3.00×10^{8} m/s, Planck's constant (h) = 6.63×10^{-34} J.s

$\nu = 0.5 \times 10^{13}\ s^{-1}$ and $E_{photon} = 3.315 \times 10^{-21}$ J

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أحصل على نسختك من كتاب
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