Quantum Theory

Define –

frequency: $\nu \rightarrow$ The # of cycles a wave undergoes per second. Expressed in units of $\frac{1}{s} = s^{-1} = Hz$

wavelength: $\lambda \rightarrow$ The distance between any point on a wave and the corresponding point on the next wave. Ie → The distance a wave travels in one cycle.

speed of light: $C \rightarrow$ a constant. Speed at which EMR travels in a vacuum.
$C = 2.99792458 \times 10^8$ m/s

amplitude: The height of the crest (or depth of the trough) of a wave. This is related to the intensity of the energy.

electromagnetic spectrum: The continuum of wavelengths of radiant energy

infrared region (IR): The region of the EM spectrum between the microwave and visible regions.

ultraviolet region (UV): The region of the EM spectrum between the visible and the x-ray regions.

quantum number: A number that specifies a property of an orbital or e^-.

photoelectric effect: The observation that when monochromatic light of sufficient frequency shines on a metal, an electric current is produced.

Frequency and wavelength have a reciprocal relationship to each other. Given this, fill in the blanks:

Radiation with a high frequency has a short wavelength. Therefore, the opposite is true. Radiation with a low frequency has a long wavelength.

A wave with high amplitude is brighter than one with low amplitude.

Speed of a wave is expressed in terms of:

$\lambda = m$
$\nu = s^{-1}$

speed is the distance traveled per unit time. Product of frequency (cycles per second) and wavelength (meters per cycle)

$$\text{Speed} = (\nu)(\lambda) = \frac{\text{cycles}}{s} \times \frac{m}{\text{cycles}} = m/s$$

* Note that λ is a distance. This can be expressed in m, nm (10^{-9} m), Å (10^{-10} m), etc. To convert, though, it is best to first put λ in m, then do the rest of the conversion or calculation.

Example:

While getting an x-ray (λ=1.00 Å) a radio is playing (λ=325 cm) and you look out at the clear blue sky (λ=473 nm) wishing you hadn't been involved in a bike accident causing you to miss Chemistry. Since your mind is thinking about Chemistry anyway, you decide to convert each wavelength into frequency (s^{-1}). (Assume: radiation is traveling at the speed of light rounded off to three significant figures.) $C = 3.00 \times 10^8$ m/s @ 3 sig figs

$$C = (\nu)(\lambda) \Rightarrow \nu = \frac{C}{\lambda}$$

X-Ray

$1.00 \text{ Å} = 1.00 \times 10^{-10}$ m

$$\nu = \frac{3.00 \times 10^8 \text{ m}}{3.00 \times 10^{-10} \text{ m/s}} = 3.00 \times 10^{-18} \ s^{-1}$$

Radio

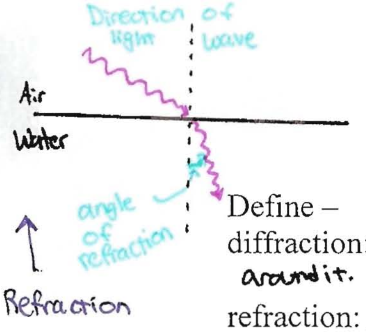
$325 \text{ cm} = 325 \times 10^{-2}$ m

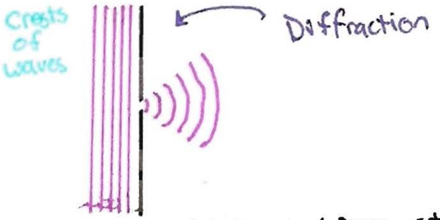
$$\nu = \frac{3.00 \times 10^8 \text{ m/s}}{325 \times 10^{-2} \text{ m}} = 9.23 \times 10^7 \ s^{-1}$$

Sky

$473 \text{ nm} = 473 \times 10^{-9}$ m

$$\nu = \frac{3.00 \times 10^8 \text{ m/s}}{473 \times 10^{-9} \text{ m}} = 6.34 \times 10^{14} \ s^{-1}$$





Define –

diffraction: The phenomenon in which a wave striking the edge of an object bends around it. A wave passing through a slit as wide as its wavelength forms a circular wave.

refraction: A phenomenon in which a wave changes its speed and, therefore, its direction as it passes through a phase boundary.

Planck's constant: $h \rightarrow$ A proportionality constant relating the energy and the frequency of a photon. $h = 6.626 \times 10^{-34}$ J·s

quantum: A packet of energy equal to $h\nu$. The smallest quantity of energy that can be emitted or absorbed.

Example:

Instead of going to the dining commons for dinner, you decide to heat up your meal in your dorm microwave. If your microwave emits radiation with a wavelength of 1.20 cm, what is the energy of one photon of this radiation?

$$E = h\nu = \frac{hc}{\lambda}$$

$$E = \frac{(6.626 \times 10^{-34}\ J \cdot s)(3.00 \times 10^{8}\ m/s)}{1.20 \times 10^{-2}\ m} = 1.66 \times 10^{-23}\ J$$

$h = 6.626 \times 10^{-34}$ J·s

$c = 3.00 \times 10^{8}$ m/s

$\lambda = 1.20 cm = 1.20 \times 10^{-2}$ m

Bohr model of the Hydrogen atom

Three postulates –

1. The H atom only has certain allowable energy levels, called stationary states. Each state is associated with a fixed circular orbit of the e^- around the nucleus.
2. The atom does not radiate energy while in one of its stationary states. Ie → the atom does not change energy while the e^- moves w/in an orbit.
3. The atom changes to another stationary state (e^- moves to another orbit) only by absorbing or emitting a photon whose energy equals the difference in energy between the two states.

$E_{photon} =$
$E_A - E_B = h\nu$
where $E_A > E_B$
(A is higher than B)

Remember – the Bohr model is a great model for hydrogen. Unfortunately, it failed to predict the spectral lines of anything beyond hydrogen. However, we can use this model to calculate energy levels of an atom. It explains that an atomic spectrum is not continuous because the atom's energy has only certain discrete levels, or states

Calculate the quantity of energy needed to completely remove the electron from an H atom. Ie – what is ΔE for H (g) → H^+ (g) + e^-

$$\Delta E = E_{final} - E_{initial} = -2.18 \times 10^{-18}\ J \left(\frac{1}{n^2_{final}} - \frac{1}{n^2_{initial}}\right)$$

$n_{final} = \infty$

$n_{initial} = 1$

$$\Delta E = -2.18 \times 10^{-18}\ J \left(\frac{1}{\infty^2} - \frac{1}{1^2}\right)$$

$$= -2.18 \times 10^{-18}\ J\ (0 - 1) = 2.18 \times 10^{-18}\ J$$

ΔE is + ~~becau~~ because energy is absorbed to remove the e^- from the viscinity of the nucleos.

Wave-partical duality

Define –

de Broglie wavelength: The wavelength of a moving particle obtained from the de Broglie equation. $\lambda = \frac{h}{mu}$

for this, matter behaves as though it moves in a wave

uncertainty principle: The principle stated by Werner Heisenberg that it is impossible to know simultaneously the exact position and velocity of a particle. The principle becomes important only for particles of very small masses.

Example:
An electron moving near an atomic nucleus has a speed of 6×10^6 m/s ± 1%. What is the uncertainty in its position?

Δx

Δu = uncertainty in speed = 1% of u

$\Delta u = 0.01\,(6 \times 10^6 \text{ m/s}) = 6 \times 10^4 \text{ m/s}$

Δu is found by multiplying the uncertainty in the speed by the speed.

$m = 9.11 \times 10^{-31}$ kg (mass of e^-)

$$\Delta x \cdot m\,\Delta u \geq \frac{h}{4\pi}$$

$$\Delta x \cdot (9.11 \times 10^{-31} \text{ kg})(6 \times 10^4 \text{ m/s}) \geq \frac{6.626 \times 10^{-34} \ \frac{\text{kg} \cdot \text{m}^2}{\text{s}}}{4\pi}$$

$$\Delta x \geq 1 \times 10^{-9} \text{ m}$$

- The uncertainty in the e^-'s position is about 10x greater than the diameter of the entire atom (10^{-10} m). ∴, we have no precise idea where in the atom the e^- is located.