Department of Chemistry
University of Texas at Austin

More Practice: Energy, Frequency, Wavelength and the Photoelectric Effect.

Tera 10^{12}
Giga 10^{9}
Mega 10^{6}
Kilo 10^{3}
Hecto 10^{2}
Deca 10^{1}
□
deci 10^{-1}
centi 10^{-2}
milli 10^{-3}
micro 10^{-6}
nano 10^{-9}
pico 10^{-12}
fempto 10^{-19}

There are two equations you should know:

E = hν and c = $\nu\lambda$ $\quad \nu = \frac{c}{\lambda} \;\therefore\; E = \frac{hc}{\lambda}$

E = energy (J)

λ = wavelength (m)

ν = frequency (Hz or s^{-1})

h = Planck's constant, $6.626\text{x}10^{-34}$ J·s

c = the speed of light in a vacuum, 3.00×10^{8} $m{\cdot}s^{-1}$

During the course of this unit, you should become very comfortable with the process of solving problems like the following. You may also want to review scientific prefixes (ex: nano- means 10^{-9}).

1. Radiowaves are about 1m long. Convert this to frequency, in MHz.

$$\frac{c}{\lambda} = \frac{\nu\lambda}{\lambda} \Rightarrow \frac{c}{\lambda} = \nu = \frac{3.0\times10^{8}\, {}^{m}/_{s}}{1\, m} = 3.0\times10^{8}\, Hz \qquad \frac{1}{s} = Hz$$

2. A hypothetical wave has 6.6 J of energy. What is its hypothetical, approximate frequency?

$$E = h\nu \quad \nu = \frac{E}{h} \qquad \nu = \frac{6.6J}{6.626\times10^{-34}\, J{\cdot}s} = 0.9\times10^{34}\, Hz$$

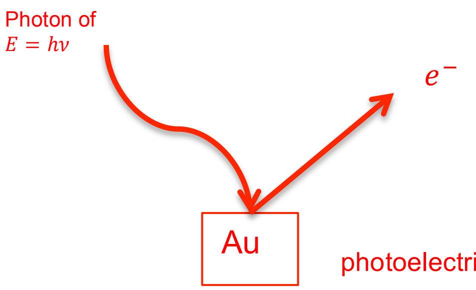
3. A photon with enough energy, 5.1 electron volts (eV) of energy - to be precise, will eject an electron from a piece of gold! What frequency and wavelength does light with this energy have? Note: 1eV = 1.60×10^{-19} joules

$$\nu = \frac{E}{h} = \frac{(5.1eV)\left(1.60\times10^{-19}\, {}^{J}/_{eV}\right)}{(6.626\times10^{-34} J\cdot s)} = 1.2\times\times10^{15}\, Hz$$

$$\lambda = \frac{c}{\nu} = \frac{(3.0\times10^{8}\, {}^{m}/_{s})}{\left(1.2\times10^{15}\, {}^{1}/_{s}\right)} = 2.5\times10^{-7}\, m$$

4. The question above describes the photoelectric effect. Use the space below to draw a picture illustrating this effect. Describe this figure and explain how frequency and work function (Φ) relate to the kinetic energy of the emitted electron.

1 photon → 1 e^- ejected if $h\nu \geq \Phi$. Nothing happens if $h\nu < \Phi$. If $h\nu > \Phi$, the kinetic energy of the ejected electron increases as the E difference (between $h\nu$ & Φ) increases.



photoelectric effect

5. Recalling the information from question 3, what would happen if you were to shine a light of 6.5 eV on the gold surface? How is this the same or different from using light of 3.0 eV? What if the metal was Cesium (Φ = 2.1eV) or Platinum (Φ = 6.35eV) instead?

$6.5\ eV > \Phi(5.1\ eV)$, so the electron would be ejected. Light of $3.0\ eV$ cannot overcome the work function, so no electron would be ejected. For Cs, both $6.5\ eV$ and $3.0\ eV$ would eject an electron, but the electron will be faster with the $6.5\ eV$ light. Only the $6.5\ eV$ light will be enough to eject an electron from Pt, but it will move slower than that ejected fro Au.

6. A red laser pointer emits light with a wavelength of 700nm. A fancy green laser pointer emits light with a wavelength of 500nm. Which emits more energy per photon? (You might also compare the two tools' operating frequencies.)

$$green = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34} J\cdot s)(3.0\times10^{8}\ {}^{m}/_{s})}{(500\times10^{-9} m)} = 4.0\times10^{-19}\ J\ for\ green$$

$$red = E = h\nu = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34} J\cdot s)(3.0\times10^{8}\ {}^{m}/_{s})}{(700\times10^{-9} m)} = 0.028\times10^{-17} J = 2.8\times10^{-19}\ J\ for\ red$$

note: $E_{green} > E_{red}$

7. UVA radiation has a wavelength of about 360nm. How much energy, in Joules, does a photon of UVA light transfer?

$E = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34} J\cdot s)(3.0\times10^{8}\ {}^{m}/_{s})}{360\times10^{-9} m} = 5.5\times10^{-19} J$ note: $UV > green > red$

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8. UVA penetrates more deeply into the skin, but UVB more readily causes sunburn. These UVB photon travel with a frequency of about 1.0 x 10^{15}. How much more energy do they carry?

$E = h\nu = (6.626\times10^{-34} J\cdot s)(1.0\times10^{15}\ {}^{1}/_{s}) = 6.626\times10^{-19}\ J$

note: $UVB > UVA > green > red$

9. A student removes the spinning plate from his microwave oven. He places a chocolate bar inside on a paper plate and zaps it for 10 seconds. Removing the candy, he sees two melted spots approximately 6cm apart. The microwave says on the back that it operates at 24.5 GHz. Considering that the speed of light in air is *very* close to the speed of light in a vacuum, he calculates the wavelength of a microwave. Show his work... then maybe try the experiment yourself!

$$c = \lambda\nu$$

$$\lambda = \frac{c}{\nu} = \frac{(3.0\times10^{8}\ {}^{m}/_{s})}{(24.5\times10^{9}\ {}^{1}/_{s})} = 0.012\ m = 12\ cm$$

10. The wavelength of a diagnostic x-ray is only 0.01 nm. What frequency does the doctor's machine operate with?

$$c = \nu\lambda$$

$$\nu = \frac{c}{\lambda} = \frac{(3.0\times10^{8}\ {}^{m}/_{s})}{0.01\times10^{-9} m} = 300\times10^{17}\ Hz = 3.0\times10^{19}\ Hz$$

11. Test yourself! Can you name the colors of the rainbow? Order the regions of the *visible* and *invisible* (gamma ray, microwave, x-rays, radio-wave, infrared, ultraviolet) electromagnetic spectrum according to their energies. Are the corresponding frequencies high or low?

High energy, ____↑____ frequency, _____↓____ wavelength

gamma ray

x-ray

UV

violet

indigo

blue

green

yellow

orange

red

infrared

microwave

radiowave

Low energy ___↓_____ frequency, ____↑_____ wavelength