Chemistry H

Exercise 4.1a(H)

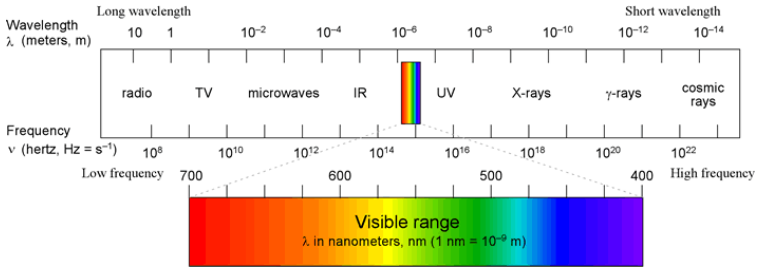
Wavelength & Frequency

Name: _____

Date: _____ Per: _____

Electromagnetic (EM) radiation exhibits wave properties as it moves through space. These properties determine how it interacts with matter and include:

- **wavelength (λ)** – the distance between successive waves (measured in units of length)
- **frequency (υ)** – the number of waves that occur in 1 second (measured in hertz (Hz), /s, or s^{-1})
- **wave speed** – all EM waves move at the same speed; the speed of light (3.00×10^8 m/s)



DIRECTIONS: Answer the following in the space provided.

1. What type of light has a wavelength of:

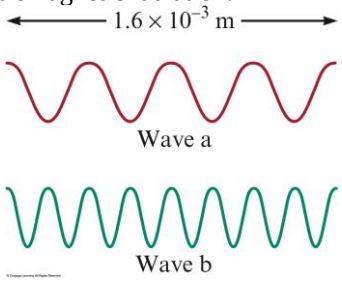
   a. 2.0×10^{-3} m ___*microwaves*___

   b. 4.5×10^{-7} m ___*ultraviolet*___

   c. 123 cm ___*radio/TV*___

   d. 6.7×10^{-12} m ___*gamma radiation*___

Consider the following waves representing electromagnetic radiation:



2. Which wave has the longer wavelength? ___*Wave a*___

   a. Calculate the wavelength.

1.6×10^{-3} m / 4 waves = 4.0×10^{-4} m

4.0×10^{-4} m

3. Which wave has the greater velocity? Explain. ___*All EM radiation moves at the speed of light, so their velocities would be equal moving through the same medium (i.e., a vacuum, glass, air, etc.).*___

4. According to the Bohr model of the hydrogen atom, how are atomic spectra produced? ___*When electrons move from higher energy levels (excited) to lower levels (approaching ground state), the excess energy is released as EM radiation.*

5. Which of the following transitions would produce a photon with the greatest energy? Why?

   n = 1 → n = 5
   n = 4 → n = 3
   n = 5 → n = 2
   n = 3 → n = 4

   n = 5 → n = 2 would produce a photon with the greatest energy because the electron is dropping from a higher energy level to a lower energy level (unlike n = 1 → n = 5 & n = 3 → n = 4) and the number of energy levels is greater than the last alternative (n = 4 → n = 3).

Answers: 2a) 0.00040 m

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The Planck constant (denoted *h*), also called Planck's constant, is a physical constant used to describe the sizes of quanta in quantum mechanics. It is named after Max Planck, one of the founders of quantum theory. The Planck constant is the proportionality constant between energy(*E*) of a photon and the frequency of its associated electromagnetic wave (*v*). This relation between the energy and frequency is called the Planck relation or the Planck–Einstein equation:

$$E = hv$$

Using the following simple relation between frequency (*v*), speed of light (*c*), and wavelength (λ),

$$v = \frac{c}{\lambda}$$

the Planck relation becomes the following

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

$c = 3.000 \times 10^{8}$ m/s
$h = 6.626\,2 \times 10^{-34}$ J•s (or J/Hz)

DIRECTIONS: Answer the following in the space provided.

6. What is the wavelength of a wave having a frequency of 3.76×10^{14} s^{-1}?

λ = ?
$v = 3.76 \times 10^{14}$ s^{-1} (s^{-1} = /s)
$v = \frac{c}{\lambda} \Rightarrow \lambda = \frac{c}{v} \Rightarrow \lambda = \frac{3.000 \times 10^{8}\ m/s}{3.76 \times 10^{14}\ /s} = 7.9787 \times 10^{-7}$ m

7. What is the frequency of a 6.9×10^{-13} m wave?

v = ?
$\lambda = 6.9 \times 10^{-13}$ m
$v = \frac{c}{\lambda} \Rightarrow v = \frac{3.000 \times 10^{8}\ m/s}{6.9 \times 10^{-13}\ m} = 4.3478 \times 10^{20}$ Hz

8. What is the wavelength of a 2.990 MHz wave?

λ = ?
v = 2.990 MHz $\Rightarrow 2.990 \times 10^{6}$ Hz (Hz = /s)
$v = \frac{c}{\lambda} \Rightarrow \lambda = \frac{c}{v} \Rightarrow \lambda = \frac{3.000 \times 10^{8}\ m/s}{2.990 \times 10^{6}\ /s} = 100.334$ m

9. What is the wavelength of a 1.28×10^{17} Hz wave?

λ = ?
$v = 1.28 \times 10^{17}$ Hz (Hz = /s)
$v = \frac{c}{\lambda} \Rightarrow \lambda = \frac{c}{v} \Rightarrow \lambda = \frac{3.000 \times 10^{8}\ m/s}{1.28 \times 10^{17}\ /s} = 2.3437 \times 10^{-9}$ m

10. What is the frequency of a 2600 cm wave?

v = ?
λ = 2600 cm $\Rightarrow$ 26 m
$v = \frac{c}{\lambda} \Rightarrow v = \frac{3.000 \times 10^{8}\ m/s}{26\ m} = 1.1538 \times 10^{7}$ Hz

11. What is the wavelength of 109.60 MHz wave?

λ = ?
v = 109.60 MHz $\Rightarrow$ 1.0960×10^{8} Hz (Hz = /s)
$v = \frac{c}{\lambda} \Rightarrow \lambda = \frac{c}{v} \Rightarrow \lambda = \frac{3.000 \times 10^{8}\ m/s}{1.0960 \times 10^{8}\ /s} = 2.7372$ m

12. What is the energy of a 7.66×10^{14} Hz wave?

E = ?
$v = 7.66 \times 10^{14}$ Hz (Hz = /s)

$E = hv$
$E = (6.6262 \times 10^{-34}\ J•s)(7.66 \times 10^{14}\ /s) = 5.0756 \times 10^{-19}$ J

13. What is the frequency of a wave carrying 8.35×10^{-18} J of energy?

v = ?
$E = 8.35 \times 10^{-18}$ J
$E = hv \Rightarrow v = \frac{E}{h} \Rightarrow v = \frac{8.35 \times 10^{-18}\ J}{6.6262 \times 10^{-34}\ J•s} = 1.2601 \times 10^{16}$ Hz

14. What is the energy of a 3.12×10^{18} s^{-1} wave?

E = ?
$v = 3.12 \times 10^{18}$ s^{-1} (s^{-1} = /s)

$E = hv$
$E = (6.6262 \times 10^{-34}\ J•s)(3.12 \times 10^{18}\ /s) = 2.0673 \times 10^{-15}$ J

15. What is the frequency of a 1.310×10^{-22} J wave?

v = ?
$E = 1.310 \times 10^{-22}$ J

$E = hv \Rightarrow v = \frac{E}{h} \Rightarrow v = \frac{1.310 \times 10^{-22}\ J}{6.6262 \times 10^{-34}\ J•s} = 1.9770 \times 10^{11}$ Hz

16. What is the energy of a 9330 cm wave?

E = ?
λ = 9330 cm $\Rightarrow$ 93.3 m

$E = \frac{hc}{\lambda} \Rightarrow E = \frac{(6.6262 \times 10^{-34}\ J•s)(3.000 \times 10^{8}\ m/s)}{93.3\ m} = 2.1306 \times 10^{-27}$ J

17. What is the wavelength of a 1.528×10^{-13} J wave?

λ = ?
$E = 1.528 \times 10^{-13}$ J

$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E}$

$\lambda = \frac{(6.6262 \times 10^{-34}\ J•s)(3.000 \times 10^{8}\ m/s)}{1.528 \times 10^{-13}\ J} = 1.300955 \times 10^{-12}$ m

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Answers: 6) 7.98×10^{-7} m 7) 4.3×10^{20} Hz 8) 100.3 m 9) 2.34×10^{-9} m 10) 1.2×10^{7} Hz 11) 2.737 m 12) 5.08×10^{-19} J 13) 1.26×10^{16} Hz 14) 2.07×10^{-15}J 15) 1.977×10^{11} Hz 16) 2.13×10^{-27} J 17) 1.301×10^{-12} m