

Atomic Physics

Problem A**QUANTUM ENERGY****PROBLEM**

Find the energy of a photon of red light, having a wavelength of 690 nm.

SOLUTION

Given: $\lambda = 6.90 \times 10^{-7} \text{ m}$

Unknown: $f = ?$ $E = ?$

Choose the equation(s) or situation: Use the equation for the energy of a light quantum, given on page 832.

$$E = hf$$

Use the equation relating frequency to wavelength, given on page 522.

$$c = \lambda f$$

Rearrange the equation(s) to isolate the unknown(s): Rearrange the equation to solve for the frequency.

$$f = \frac{c}{\lambda} = \frac{3.0 \times 10^8 \text{ m/s}}{6.90 \times 10^{-7} \text{ m}} = 4.3 \times 10^{14} \text{ Hz}$$

$$E = hf = \frac{(6.63 \times 10^{-34} \text{ J} \cdot \text{s})(4.3 \times 10^{14} \text{ Hz})}{1.60 \times 10^{-19} \text{ J/eV}} = \boxed{1.8 \text{ MeV}}$$

ADDITIONAL PRACTICE

- Determine the energy of a photon of green light, having a wavelength of 527 nm.
- What is the energy of a photon of blue light, having a wavelength of 430.8 nm?
- Calculate the frequency of ultraviolet (UV) light, having the energy of 20.7 eV.
- Microwave ovens work by vibrating the water molecules in food, causing the food to warm up. Microwaves can reach energies as high as 1.24×10^{-3} eV. At what frequency is this?
- Calculate the frequency of infrared (IR) light, having the energy of 1.78 eV.
- An X ray can have an energy of 12.4 MeV. To what wavelength does this correspond?
- A neutron has 939.57 MeV of energy. If a photon had the same energy as a neutron, what would be the photon's wavelength? The visible part of the spectrum ranges from 700 nm – 400 nm. Would this wavelength lie within the visible spectrum?
- Calculate the wavelength of a radio wave that has an energy of 3.1×10^{-6} eV.

Atomic Physics

Additional Practice A

Givens

Solutions

1. $\lambda = 527 \text{ nm} = 5.27 \times 10^{-7} \text{ m}$

$$E = hf = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{5.27 \times 10^{-7} \text{ m}} = \boxed{3.77 \times 10^{-19} \text{ J}}$$

2. $\lambda = 430.8 \text{ nm}$
 $= 4.308 \times 10^{-7} \text{ m}$

$$E = hf = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{4.308 \times 10^{-7} \text{ m}} = \boxed{4.62 \times 10^{-22} \text{ J}}$$

3. $E = 20.7 \text{ eV}$

$$f = \frac{E}{h} = \frac{(20.7 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})}{6.63 \times 10^{-34} \text{ J}\cdot\text{s}} = \boxed{5.00 \times 10^{15} \text{ Hz}}$$

4. $E = 1.24 \times 10^{-3} \text{ eV}$

$$f = \frac{E}{h} = \frac{(1.24 \times 10^{-3} \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})}{6.63 \times 10^{-34} \text{ J}\cdot\text{s}} = \boxed{2.99 \times 10^{11} \text{ Hz}}$$

5. $E = 1.78 \text{ eV}$

$$f = \frac{E}{h} = \frac{(1.78 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})}{6.63 \times 10^{-34} \text{ J}\cdot\text{s}} = \boxed{4.30 \times 10^{14} \text{ Hz}}$$

6. $E = 12.4 \text{ MeV}$
 $= 1.24 \times 10^7 \text{ eV}$

$$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{(1.24 \times 10^7 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})} = \boxed{1.00 \times 10^{-13} \text{ m}}$$

7. $E = 939.57 \text{ MeV}$
 $= 9.3957 \times 10^8 \text{ eV}$

$$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{(9.3957 \times 10^8 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})} = \boxed{1.32 \times 10^{-15} \text{ m}}$$

$$1.32 \times 10^{-15} \text{ m} = 1.32 \times 10^{-6} \text{ nm}$$

If a photon were to have this wavelength, it would not lie within the visible part of the spectrum.

8. $E = 3.1 \times 10^{-6} \text{ eV}$

$$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{(3.1 \times 10^{-6} \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})} = \boxed{0.401 \text{ m}}$$

Additional Practice B

1. $\lambda = 240 \text{ nm} = 2.4 \times 10^{-7} \text{ m}$
 $hf_i = 2.3 \text{ eV}$

$$KE_{\max} = \frac{hc}{\lambda} - hf_i$$

$$KE_{\max} = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{2.4 \times 10^{-7} \text{ m}} - 2.3 \text{ eV}$$

$$KE_{\max} = 5.2 \text{ eV} - 2.3 \text{ eV} = \boxed{2.9 \text{ eV}}$$