Assignment 4 Solutions

Chapter 7 # 7.14, 7.22, 7.24, 7.28, 7.32, 7.36, 7.38, 7.40.

7.14. **Collect and Organize**

To answer why infrared (IR) light is "safe" and ultraviolet (UV) light may cause cancer, we need to look at their relative energies.

Analyze

High-energy light may cause cellular damage by disrupting chemical bonds. Energy is inversely related to the wavelength of light: $E = hc/\lambda$.

Solve

UV light has a shorter wavelength than IR and therefore has a higher energy. This energy is enough to break chemical bonds or ionize molecules. IR light, however, with a longer wavelength and lower energy, does not cause cellular damage—its energy is too low.

Think About It

Both IR and UV light are outside of the visible (to our eyes) range in the electromagnetic spectrum.

7.22. **Collect and Organize**

Given the frequency of an AM radio station, (680 kHz), we are to calculate its wavelength and compare it to the wavelength of infrared radiation emitted by Earth (λ = 15 mm).

Analyze

Wavelength can be calculated using

$$\lambda = c/\nu$$

where λ is in meters, $c = 3.00 \times 10^8$ m/s, and ν is in hertz (per second). We have to convert kilohertz to hertz (1 kHz = 1000 Hz).

Solve

$$\lambda = \frac{3.00 \times 10^8 \text{ m/s}}{680 \times 10^3 \text{ s}^{-1}} = 441 \text{ m}$$

The wavelength of the AM radio station (a) is longer than the 15 mm wavelength for IR radiation (b).

Think About It

Radio waves are measured on the meter scale; light waves (including IR and UV) are measured on the nanometer scale.

7.24. **Collect and Organize**

Red light has a wavelength of about 600 nm. Green light has a wavelength of about 550 nm. We are asked to compare the frequencies of these two colors of lights and state which is higher.

Analyze

We can calculate the frequency for each color of light using $\nu = c/\lambda$. Wavelength must be expressed in meters for this calculation (1 nm = 1×10^{-9} m).

Solve

$$\nu_{\text{red}} = \frac{3.00 \times 10^{8}\ \text{m/s}}{600 \times 10^{-9}\ \text{m}} = 5.00 \times 10^{14}\ \text{s}^{-1}$$

$$\nu_{\text{green}} = \frac{3.00 \times 10^{8}\ \text{m/s}}{550 \times 10^{-9}\ \text{m}} = 5.45 \times 10^{14}\ \text{s}^{-1}$$

The green light (b) has a higher frequency than the red light (a).

Think About It

We did not have to calculate the actual frequencies for this problem. If we keep in mind that wavelength decreases along the spectrum of colors in the rainbow (ROYGBIV) and we know that frequency is inversely proportional to wavelength, then frequency increases along the spectrum (ROYGBIV) and green light has a higher frequency (and shorter wavelength) than red light.

7.28. **Collect and Organize**

We are to consider whether Fraunhofer lines are atomic emissions or absorptions.

Analyze

Fraunhofer lines show up as dark lines in the broad band of color.

Solve

The colors that are missing from the spectrum have been absorbed, hence they are not observed.

7.32. **Collect and Organize / Analyze**

We are to define photon.

Solve

A photon is the smallest indivisible packet or particle of light energy.

Think About It

The energy of a photon can be related to its frequency ($E = h\nu$) and wavelength ($E = hc/\lambda$).

7.36. **Collect and Organize**

From a list, we are to choose which have quantized values.

Analyze

Something is quantized if it is present only in discrete amounts and can only have whole-number multiples of the smallest amount.

Solve

(a) The pitch of a note on a slide trombone can be varied continuously, so this is not a quantized value.
(b) The pitch of a note on a flute depends on which holes are covered or open, so this is a quantized value.
(c) The wavelengths of light produced by a heating element are continuous, so this is not a quantized value.
(d) The wind speed on top of Mt. Everest can vary continuously, so this is not a quantized value.

Think About It

Any quantity that is quantized has to have changes occurring in discrete steps.

7.38. **Collect and Organize**

The work function equation to answer this problem is

$$\mathrm{KE_{electron}} = h\nu - \Phi$$

We are asked to determine the wavelength corresponding to the work function to eject one electron.

Analyze

The kinetic energy for the electron ejected by the maximum wavelength must be zero because no additional energy is supplied to the electron by the incident radiation other than ejecting it. Therefore, the frequency of the light to eject the electron would be

$$0 = h\nu - \Phi \quad \text{or} \quad \nu = \Phi/h$$

The work function is the energy required to eject an electron. This is equivalent to the first ionization energy (given as 6.24×10^{-19} J). The wavelength can then be found from ν using $\lambda = c/\nu$.

Solve

$$\nu = \frac{6.24 \times 10^{-19}\ \mathrm{J}}{6.626 \times 10^{-34}\ \mathrm{J \cdot s}} = 9.417 \times 10^{14}\ \mathrm{s^{-1}}$$

$$\lambda = \frac{3.00 \times 10^{8}\ \mathrm{m/s}}{9.417 \times 10^{14}\ \mathrm{s^{-1}}} = 3.19 \times 10^{-7}\ \mathrm{m\ or\ 319\ nm}$$

Think About It

This wavelength (319 nm) is in the UV region of the electromagnetic spectrum.

7.40. **Collect and Organize**

We can use the equation for the photovoltaic effect to determine if electrons could be ejected from tantalum using light with a wavelength of 500 nm.

Analyze

As long as the energy of the light that shines on the metal is greater than the work function for tantalum ($\Phi = 6.81 \times 10^{-19}$ J), the light will eject electrons and tantalum would therefore be useful in a voltaic cell. The energy of the light can be calculated from $E = hc/\lambda$.

Solve

The energy of light of 500 nm wavelength can be found as

$$E = \frac{6.626 \times 10^{-34}\ \text{J} \cdot \text{s} \times 3.00 \times 10^{8}\ \text{m/s}}{5.00 \times 10^{-7}\ \text{m}} = 3.98 \times 10^{-19}\ \text{J}$$

This energy is less than the work function for tantalum ($\Phi = 6.81 \times 10^{-19}$ J), so tantalum could not be used to convert solar energy at 500 nm to electricity.

Think About It

The wavelength of light that would be needed to eject electrons from tantalum would be

$$\lambda = \frac{hc}{\Phi} = \frac{6.626 \times 10^{-34}\ \text{J} \cdot \text{s} \times 3.00 \times 10^{8}\ \text{m/s}}{6.81 \times 10^{-19}\ \text{J}} = 2.92 \times 10^{-7}\ \text{m or } 292\ \text{nm}$$