# Solutions to Problems : Chapter 30
# Problems appeared on the end of chapter 30 of the Textbook

## (Problem 2, 10, 14, 28, 36)

2. **Picture the Problem**: The human body can be considered a blackbody radiator with a surface temperature of 95 °F. The peak radiation frequency and wavelength are functions of that temperature.

   **Strategy:** Solve Wien's Displacement Law (equation 30-1) for the peak frequency. Remember to convert the Fahrenheit temperature to Kelvin. Use equation 14-1 to calculate the wavelength, where the wave speed is the speed of light.

   **Solution: 1. (a)** Calculate the peak frequency:

   $$f_{\text{peak}} = \left(5.88\times10^{10}\ \text{s}^{-1}\cdot\text{K}^{-1}\right)T$$
   $$= \left(5.88\times10^{10}\ \text{s}^{-1}\cdot\text{K}^{-1}\right)\left[\tfrac{5}{9}(95-32)+273.15\right]\text{K}$$
   $$f_{\text{peak}} = \boxed{1.81\times10^{13}\ \text{Hz}}$$

   **2. (b)** Calculate the wavelength:

   $$\lambda = \frac{c}{f} = \frac{3.00\times10^{8}\ \text{m/s}}{1.812\times10^{13}\ \text{Hz}} = \boxed{16.6\ \mu\text{m}}$$

   **Insight:** This wavelength falls in the infrared portion of the electromagnetic spectrum (see chapter 25).

10. **Picture the Problem**: UV photons have an energy of $6.5\times10^{-19}$ J. This energy corresponds to a specific frequency and wavelength.

    **Strategy:** Solve equation 30-4 for the frequency of the photon. Insert the frequency into equation 14-1 to calculate the wavelength.

    **Solution: 1.** Calculate the frequency:

    $$f = \frac{E}{h} = \frac{6.5\times10^{-19}\,\text{J}}{6.63\times10^{-34}\,\text{J}\cdot\text{s}} = \boxed{9.8\times10^{14}\ \text{Hz}}$$

    **2.** Calculate the wavelength from the frequency:

    $$\lambda = \frac{c}{f} = \frac{3.00\times10^{8}\ \text{m/s}}{9.80\times10^{14}\ \text{Hz}} = 310\ \text{nm} = \boxed{0.31\ \mu\text{m}}$$

    **Insight:** As expected, this frequency and wavelength lie in the UV spectrum (see chapter 25).

14. **Picture the Problem**: As photons interact with silver, some of the energy of the photon frees an electron from the silver atom. The remainder of the energy becomes kinetic energy of the electron.

    **Strategy:** Solve equation 30-7 for the work function of silver.

    **Solution:** Calculate the work function:

    $$K_{\max} = hf - W_0$$
    $$W_0 = hf - K_{\max} = \left(6.63\times10^{-34}\ \text{J}\cdot\text{s}\right)\left(9.95\times10^{14}\ \text{Hz}\right) - 0.180\times10^{-19}\ \text{J}$$
    $$= \boxed{6.42\times10^{-19}\ \text{J}}$$

    **Insight:** In order for a photon to eject an electron from silver, it must have a frequency greater than $9.68\times10^{14}$ Hz. At this frequency, all of the energy of the photon goes into the work function and the ejected electron has no kinetic energy.

28. **Picture the Problem**: When photons of the given frequency are incident on the two metals, some of the energy of the photon will eject the electron from the surface (work function) and the remainder of the energy will become kinetic energy of the electron.

**Strategy:** Use equation 30-4 to calculate the energy of the photon. Then insert that energy together with the work function of each metal into equation 30-5 to calculate the maximum kinetic energy.

**Solution: 1. (a)** Because $K_{\text{max}} = hf - W_0$, the photoelectrons emitted by the metal with the smaller work function will have the greater kinetic energy. The electrons ejected from the $\boxed{\text{iron}}$ surface will have the greater maximum kinetic energy because iron has a smaller work function than platinum.

**2. (b)** Calculate the photon energy:

$$E = hf = \frac{(6.63\times10^{-34}\ \text{J}\cdot\text{s})(1.88\times10^{15}\ \text{Hz})}{1.60\times10^{-19}\ \text{J/eV}} = 7.79\ \text{eV}$$

**3.** Calculate the maximum kinetic energy for electrons photoejected from platinum:

$$K_{\text{max, Pt}} = E - W_0 = 7.79\ \text{eV} - 6.35\ \text{eV} = \boxed{1.44\ \text{eV}}$$

**4.** Calculate the maximum kinetic energy for photoelectrons ejected from iron:

$$K_{\text{max, Fe}} = 7.79\ \text{eV} - 4.50\ \text{eV} = \boxed{3.29\ \text{eV}}$$

**Insight:** The cutoff frequency for platinum is $1.53\times10^{15}\ \text{Hz}$ and for iron is $1.09\times10^{15}\ \text{Hz}$. Photons with frequencies between these two values will eject photoelectrons from the iron, but not from the platinum.

36. **Picture the Problem**: A blue-green photon collides with a stationary hydrogen atom. The hydrogen atom absorbs the photon and moves forward with the same momentum as the initial photon.

**Strategy:** Calculate the initial momentum of the photon using equation 30-11. Then set that momentum equal to the momentum of the hydrogen atom after the absorption. Use equation 9-1 to calculate the speed of the hydrogen.

**Solution: 1.** Calculate the momentum of the photon:

$$p_{\text{ph}} = \frac{h}{\lambda} = \frac{6.63\times10^{-34}\ \text{J}\cdot\text{s}}{486\times10^{-9}\ \text{m}} = 1.36\times10^{-27}\ \text{kg}\cdot\text{m/s}$$

**2.** Solve for the speed of the hydrogen atom:

$$p_{\text{ph}} = p_{\text{H}} = mv$$

$$v = \frac{p_{\text{ph}}}{m} = \frac{1.364\times10^{-27}\ \text{kg}\cdot\text{m/s}}{1.674\times10^{-27}\ \text{kg}} = \boxed{0.815\ \text{m/s}}$$

**Insight:** The speed of the hydrogen atom is inversely proportional to the wavelength of the incident photon. Decreasing the wavelength of the photon will increase its momentum, and thus increase the speed of the hydrogen atom.