

Atomic Physics

Problem B**THE PHOTOELECTRIC EFFECT****PROBLEM**

Light of wavelength 3.5×10^{-7} m shines on a cesium surface. Cesium has a work function of 2.14 eV. What is the maximum kinetic energy of the photoelectrons?

SOLUTION

Given: $\lambda = 3.5 \times 10^{-7}$ m $hf_t = 2.14$ eV

Unknown: $KE_{max} = ?$

Choose the equation(s) or situation: Use the equation for the maximum kinetic energy of a photoelectron, given on page 835.

$$KE_{max} = hf - hf_t = \frac{hc}{\lambda} - hf_t$$

$$KE_{max} = \frac{(6.63 \times 10^{-34} \text{ J} \cdot \text{s})(3.0 \times 10^8 \text{ m/s})}{(1.60 \times 10^{-19} \text{ J/eV})(3.5 \times 10^{-7} \text{ m})} - 2.14 \text{ eV}$$

$$KE_{max} = \boxed{1.41 \text{ eV}}$$

ADDITIONAL PRACTICE

- Light of wavelength 240 nm shines on a potassium surface. Potassium has a work function of 2.3 eV. What is the maximum kinetic energy of the photoelectrons?
- Light of wavelength 519 nm shines on a rubidium surface. Rubidium has a work function of 2.16 eV. What is the maximum kinetic energy of the photoelectrons?
- Light of frequency 6.5×10^{14} Hz illuminates a lithium surface. The ejected photoelectrons are found to have a maximum kinetic energy of 0.20 eV. Find the threshold frequency of this metal.
- Light of frequency 9.89×10^{14} Hz illuminates a calcium surface. The ejected photoelectrons are found to have a maximum kinetic energy of 0.90 eV. Find the threshold frequency of this metal.
- The threshold frequency of platinum is 1.36×10^{15} Hz. What is the work function of platinum?
- The threshold frequency of copper is 1.1×10^{15} Hz. What is the work function of copper?
- Manganese has a work function of 4.1 eV. What is the wavelength of the photon that will just have the threshold energy for manganese?

- 8.** Cobalt has a work function of 5.0 eV. What is the wavelength of the photon that will just have the threshold energy for cobalt?
- 9.** Light shines on a photoelectric metal and the maximum kinetic energy is measured to be 0.6 eV. What is the speed of the photoelectrons?
- 10.** Light shines on a photoelectric metal and the maximum kinetic energy is measured to be 1.2 eV. What is the speed of the photoelectrons?

Atomic Physics

Additional Practice A

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

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

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

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

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2. $\lambda = 519 \text{ nm} = 5.19 \times 10^{-7} \text{ m}$
 $hf_i = 2.16 \text{ eV}$

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

$$KE_{max} = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{(5.19 \times 10^{-7} \text{ m})(1.60 \times 10^{-19} \text{ J/eV})} - 2.16 \text{ eV}$$

$$KE_{max} = 2.40 \text{ eV} - 2.16 \text{ eV} = \boxed{0.24 \text{ eV}}$$

3. $f = 6.5 \times 10^{14} \text{ Hz}$
 $KE_{max} = 0.20 \text{ eV}$

$$f_i = \frac{hf - KE_{max}}{h}$$

$$f_i = \frac{[(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(6.5 \times 10^{14} \text{ Hz}) - (0.20 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})]}{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}$$

$$f_i = \boxed{6.0 \times 10^{14} \text{ Hz}}$$

4. $f = 9.89 \times 10^{14} \text{ Hz}$
 $KE_{max} = 0.90 \text{ eV}$

$$f_i = \frac{hf - KE_{max}}{h}$$

$$f_i = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(9.89 \times 10^{14} \text{ Hz}) - (0.90 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})}{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}$$

$$f_i = \boxed{7.72 \times 10^{14} \text{ Hz}}$$

5. $f_i = 1.36 \times 10^{15} \text{ Hz}$

$$hf_i = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(1.36 \times 10^{15} \text{ Hz})}{1.60 \times 10^{-19} \text{ J/eV}} = \boxed{5.64 \text{ eV}}$$

6. $f_i = 1.1 \times 10^{15} \text{ Hz}$

$$hf_i = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(1.1 \times 10^{15} \text{ Hz})}{1.60 \times 10^{-19} \text{ J/eV}} = \boxed{4.6 \text{ eV}}$$

7. $hf_i = 4.1 \text{ eV}$

$$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{(4.1 \text{ eV})(1.60 \times 10^{-19} \text{ eV})} = 3.0 \times 10^{-7} \text{ m} = \boxed{300 \text{ nm}}$$

8. $hf_i = 5.0 \text{ eV}$

$$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{(5.0 \text{ eV})(1.60 \times 10^{-19} \text{ eV})} = 2.5 \times 10^{-7} \text{ m} = \boxed{250 \text{ nm}}$$

9. $KE_{max} = 0.62 \text{ V}$
 $m_e = 9.109 \times 10^{-31} \text{ kg}$

$$KE_{max} = hf - hf_i = \frac{1}{2} m_e v^2$$

$$v = \sqrt{\frac{2KE_{max}}{m_e}} = \sqrt{\frac{2(0.62 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})}{9.109 \times 10^{-31} \text{ kg}}}$$

$$v = \boxed{4.7 \times 10^5 \text{ m/s}}$$

10. $KE_{max} = 1.2 \text{ eV}$
 $m_e = 9.109 \times 10^{-31} \text{ kg}$

$$KE_{max} = hf - hf_i = \frac{1}{2} m_e v^2$$

$$v = \sqrt{\frac{2KE_{max}}{m_e}} = \sqrt{\frac{2(1.2 \text{ eV})(1.60 \times 10^{-19} \text{ eV})}{9.109 \times 10^{-31} \text{ kg}}}$$

$$v = \boxed{6.5 \times 10^5 \text{ m/s}}$$