KEY

First Name:________________________ Last Name:________________________

L14 – Worksheet – Photoelectric Effect 1

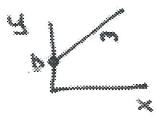
Overview

$W = hf_0$ — W: Work Function (Minimum Energy); f_0: Threshold Frequency

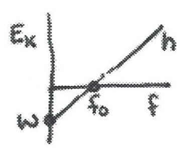
$hf = W + E_K$ — Additional Photon Energy Results in Additional Electron Kinetic Energy.

IMPORTANT

$y = mx + b$



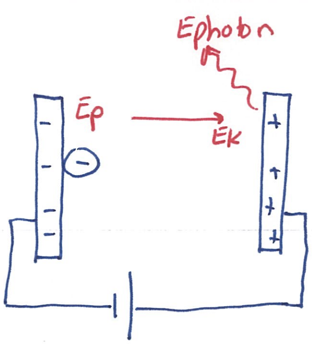
$E_K = hf - W$

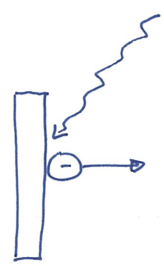


I'd be surprised if this wasn't on the final exam.

$E_{K max} = qV_{stopping}$ — q: charge on electron; $V_{stopping}$: Stopping potential (where no emitted electrons can reach the collector).

X-Ray Production versus Photoelectric Effect





$E_p \rightarrow E_K \rightarrow E_{photon}$

$q\Delta V \longrightarrow hf$

X-Ray Production

$E_{photon} \rightarrow W + E_K$

$hf \rightarrow W + \frac{1}{2}m_e v^2$

Photoelectric Effect

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Textbook Questions

Pg 718 #1: Light of wavelength 480 nm is just able to produce photoelectrons when striking a metal surface. What is the work function of the metal?

$\lambda = 480 \times 10^{-9} m$
$c = 3.0 \times 10^{8} m/s$
$W = ?$

$c = f\lambda$
$3.0 \times 10^{8} m/s = f(480 \times 10^{-9} m)$
$f = 6.25 \times 10^{14} Hz$

$W = hf_o$
$= (6.63 \times 10^{-34} J \cdot s)(6.25 \times 10^{14} Hz)$
$= 4.14375 \times 10^{-19} J$

$\frac{4.14375 \times 10^{-19} J}{1} \cdot \frac{1 eV}{1.60 \times 10^{-19} J} = 2.5898 eV$

Pg 718 #2: Blue light of wavelength 410 nm strikes a metal surface for which the work function is 2.10 eV. What is the energy of the emitted photoelectron?

$\lambda = 410 \times 10^{-9} m$
$W = 2.10 eV$
$E_K = ?$

$c = f\lambda$
$3.0 \times 10^{8} m/s = f(410 \times 10^{-9} m)$
$f = 7.317 \times 10^{14} Hz$

$\frac{2.10 eV}{1} \cdot \frac{1.60 \times 10^{-19} J}{1 eV} = 3.36 \times 10^{-19}$

$hf = W + E_K$
$(6.63 \times 10^{-34} J \cdot s)(7.317 \times 10^{14} Hz) = 3.36 \times 10^{-19} J + E_K$
$E_K = 1.4912 \times 10^{-19} J$

$\frac{1.4912 \times 10^{-19} J}{1} \cdot \frac{1 eV}{1.60 \times 10^{-19} J} = 0.9320 eV$

Pg 719 #1: A photoelectron is emitted with a kinetic energy of 2.1 eV. How fast is the electron moving?

$E_K = \frac{2.1 eV}{1} \cdot \frac{1.60 \times 10^{-19} J}{1 eV} = 3.36 \times 10^{-19} J$

$E_K = \frac{1}{2}mv^2$
$3.36 \times 10^{-19} J = \frac{1}{2}(9.11 \times 10^{-31} kg)v^2$
$v^2 = 7.377 \times 10^{11}$
$v = 8.589 \times 10^{5} m/s$

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Pg 719 #2: What is the kinetic energy of a photoelectron emitted from a cesium surface when the surface is illuminated with a 400-nm light?

$\lambda = 400 \times 10^{-9}\,m$

$c = f\lambda$

$3.0 \times 10^{8}\,m/s = f\,(400 \times 10^{-9}\,m)$

$f = 7.5 \times 10^{14}\,Hz$

$W = 2.10\,eV$

FROM TABLE 14.1 ON PG 712

$\frac{2.10\,eV}{1} \cdot \frac{1.60 \times 10^{-19}\,J}{1\,eV} = 3.36 \times 10^{-19}\,J$

$hf = W + E_K$

$(6.63 \times 10^{-34}\,J\cdot s)(7.5 \times 10^{14}\,Hz) = 3.36 \times 10^{-19}\,J + E_K$

$E_K = 1.6125 \times 10^{-19}\,J$

$\frac{1.6125 \times 10^{-19}\,J}{1} \cdot \frac{1\,eV}{1.60 \times 10^{-19}\,J} = 1.0078\,eV$

Pg 719 #3: What is the maximum speed of the electron described in Pg 719 #2?

$E_K = 1.6125 \times 10^{-19}\,J$

$m_e = 9.11 \times 10^{-31}\,kg$

$E_K = \frac{1}{2}mv^2$

$1.6125 \times 10^{-19}\,J = \frac{1}{2}(9.11 \times 10^{-31}\,kg)\,v^2$

$v^2 = 3.54 \times 10^{11}$

$v = 5.95 \times 10^{5}\,m/s$

KEY

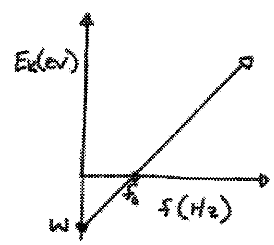
Use the following information to answer Pg 720 #8-10

The following data are taken from an experiment in which the maximum kinetic energy of photoelectrons is related to the wavelength of the photons hitting a metal surface. Use these data to answer the following questions.

Wavelength (nm)	Frequency (Hz)	Kinetic Energy (eV)
500		0.36
490		0.41
440		0.70
390		1.05
340		1.52
290		2.14
240		3.025

Pg 720 #8: Convert the wavelength given in the data table to frequency units and *sketch a quick graph* of the kinetic energy of the photoelectrons versus frequency. Label important points.

Wavelength	Frequency	Kinetic Energy
500 nm	6.0×10^{14} Hz	0.36 eV
490 nm	6.12×10^{14} Hz	0.41 eV
440 nm	6.82×10^{14} Hz	0.70 eV
390 nm	7.69×10^{14} Hz	1.05 eV
340 nm	8.82×10^{14} Hz	1.52 eV
290 nm	1.03×10^{15} Hz	2.14 eV
240 nm	1.25×10^{15} Hz	3.025 eV



Pg 720 #9: Give the value of the slope of the graph that you just drew. What is the significance of this value?

$$m = \frac{rise}{run} = \frac{3.025\text{eV} - 0.36\text{eV}}{1.25\times10^{15}\text{Hz} - 6.0\times10^{14}\text{Hz}} = \frac{2.665\text{eV}}{6.5\times10^{14}\text{Hz}} = 4.10\times10^{-15}\ \text{eV/Hz}$$

$$= 4.10\times10^{-15}\ \text{eV}\cdot\frac{1}{1/s}$$

$$= 4.10\times10^{-15}\ \text{eV}\cdot\text{s}$$

$$4.10\times10^{-15}\ \text{eV}\cdot\text{s}\cdot\frac{1.60\times10^{-19}\ \text{J}}{1\ \text{eV}} = 6.56\times10^{-34}\ \text{J}\cdot\text{s}$$

Almost Plank's Constant.

KEY

Pg 720 #10: What metal do you think was used in the previous example? Justify your answer.

Element	Work Function (eV)
Aluminium	4.08
Beryllium	5.00
Cadmium	4.07
Calcium	2.90
Carbon	4.81
Cesium	2.10
Copper	4.70
Magnesium	3.68
Mercury	4.50
Potassium	2.30
Selenium	5.11
Sodium	2.28
Zinc	4.33

$y = mx + b$

$(3.025\,eV) = (4.10 \times 10^{-15}\,eV \cdot s)(1.25 \times 10^{15}\,Hz) + b$

$b = -2.10\,eV$

where $b = -W$ (REMEMBER $E_K = hf - W$)

so $W = 2.10\,eV$, which corresponds to Cesium (TABLE 14.1, PG 712)

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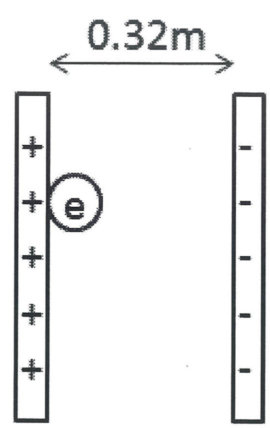
Cumulative Review from Previous Units

Use the following information to answer Q1:

Two parallel plates are 0.32m apart, with a uniform electric field of 2.5 N/C, as depicted below.



$$|\vec{E}| = 2.5\ N/C$$

An electron is moved from the positively charged plate to the negatively charged plate.

Q1: Due to being moved from one plate to the next, the electron gains ***a.bc*** x 10^{-d} eV of Electric Potential Energy, where ***a, b, c,*** and ***d*** are ___, ___, ___, and ___.

*(Record your **four digit** answer in the Numerical Response boxes below)*

8	0	0	1

$\Delta V = \frac{\Delta E_p}{q}$ and $|\vec{E}| = \frac{\Delta V}{\Delta d}$

$2.5 = \frac{\Delta V}{0.32}$

$\boxed{\Delta V = 0.80\ V}$

$\Delta E_p = q\Delta V$

$= (1e)(0.80\ V)$

$= 0.80\ eV$

$= 8.00 \times 10^{-1}\ eV$