Example 1:

A piece of potassium is illuminated with violet light having a frequency of 7.5×10^{14} Hz. Electrons are ejected from the surface with a maximum kinetic energy of 2.4×10^{-19} J.

Find (a) the energy of the photons of the violet light in electron-volts

(b) the work function (binding energy) for potassium in electron-volts

(c) the threshold frequency for potassium.

Solution:

(a)

$$E_{ph} = hf$$

$$= \frac{(6.63 \times 10^{-34}\ \text{J.s})(7.5 \times 10^{14}\ \text{Hz})}{1.6 \times 10^{-19}\ \text{J/eV}}$$

$$= 3.11\ \text{eV}$$

$$= \underline{3.1\ \text{eV}}$$

Or $E_{ph} = hf = (4.14 \times 10^{-15}\ \text{eV.s})(7.5 \times 10^{14}\ \text{Hz})$

$$= 3.11\ \text{eV}$$

$$= \underline{3.1\ \text{eV}}$$

(b)

$$W = E_{ph} - E_k$$

$$= 3.11\ \text{eV} - \frac{2.4 \times 10^{-19}\ \text{J}}{1.6 \times 10^{-19}\ \text{J/eV}}$$

$$= 3.11\ \text{eV} - 1.50\ \text{eV}$$

$$= 1.61\ \text{eV}$$

$$= \underline{1.6\ \text{eV}}$$

(c)

$$f_o = \frac{W}{h}$$

$$= \frac{(1.61\ \text{eV})(1.6 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J.s}}$$

$$= 3.88 \times 10^{14}\ \text{Hz}$$

$$= \underline{3.9 \times 10^{14}\ \text{Hz}}$$

Example 2:

When ultraviolet light of wavelength 2.8×10^{-7} m falls on a metal surface, the maximum kinetic energy of the emitted electrons is 1.4 eV.

Find: (a) the energy of a photon of ultraviolet light
(b) the binding energy (work function) of the metal
(c) the momentum of a photon of ultraviolet light.

Solution:

(a)

$$E_{ph} = \frac{hc}{\lambda}$$

$$= \frac{(6.63 \times 10^{-34}\ \text{J.s})(3.0 \times 10^{8}\ \text{m/s})}{2.8 \times 10^{-7}\ \text{m}}$$

$$= 7.10 \times 10^{-19}\ \text{J} \quad = \quad 4.44\ \text{eV}$$

$$= \underline{7.1 \times 10^{-19}\ \text{J} \quad \text{or} \quad 4.4\ \text{eV}}$$

(b)

$$E_{ph} = W + E_k$$

$$4.44\ \text{eV} = W + 1.4\ \text{eV}$$

$$\therefore W = \underline{3.0\ \text{eV}}$$

(c)

$$p = \frac{h}{\lambda}$$

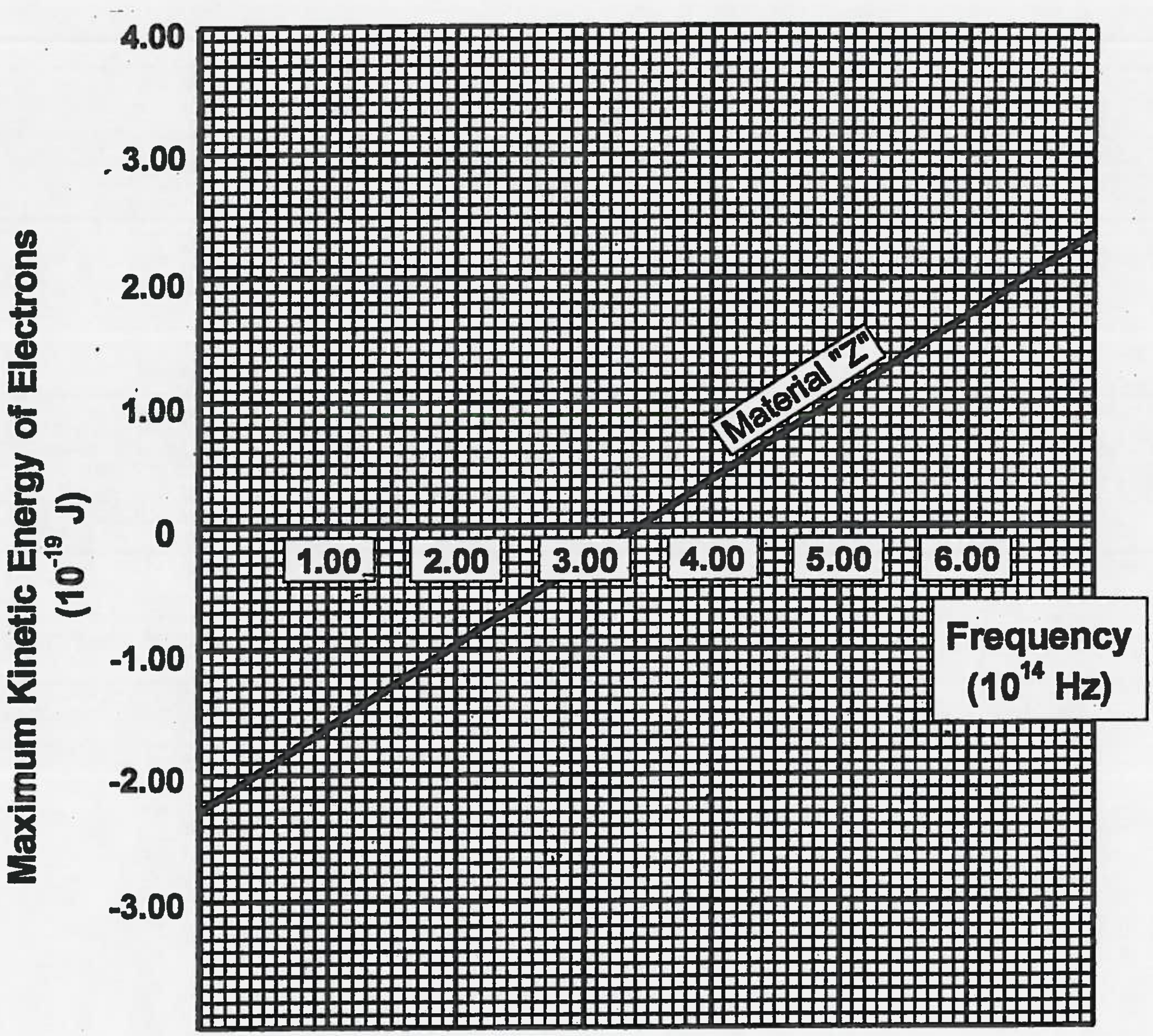
$$= \frac{6.63 \times 10^{-34}\ \text{J.s}}{2.8 \times 10^{-7}\ \text{m}}$$

$$= 2.37 \times 10^{-27}\ \text{kg.m/s}$$

$$\therefore \vec{p} = \underline{2.4 \times 10^{-27}\ \text{kg.m/s} \ \text{ in the direction of the photon}}$$

Example 3:

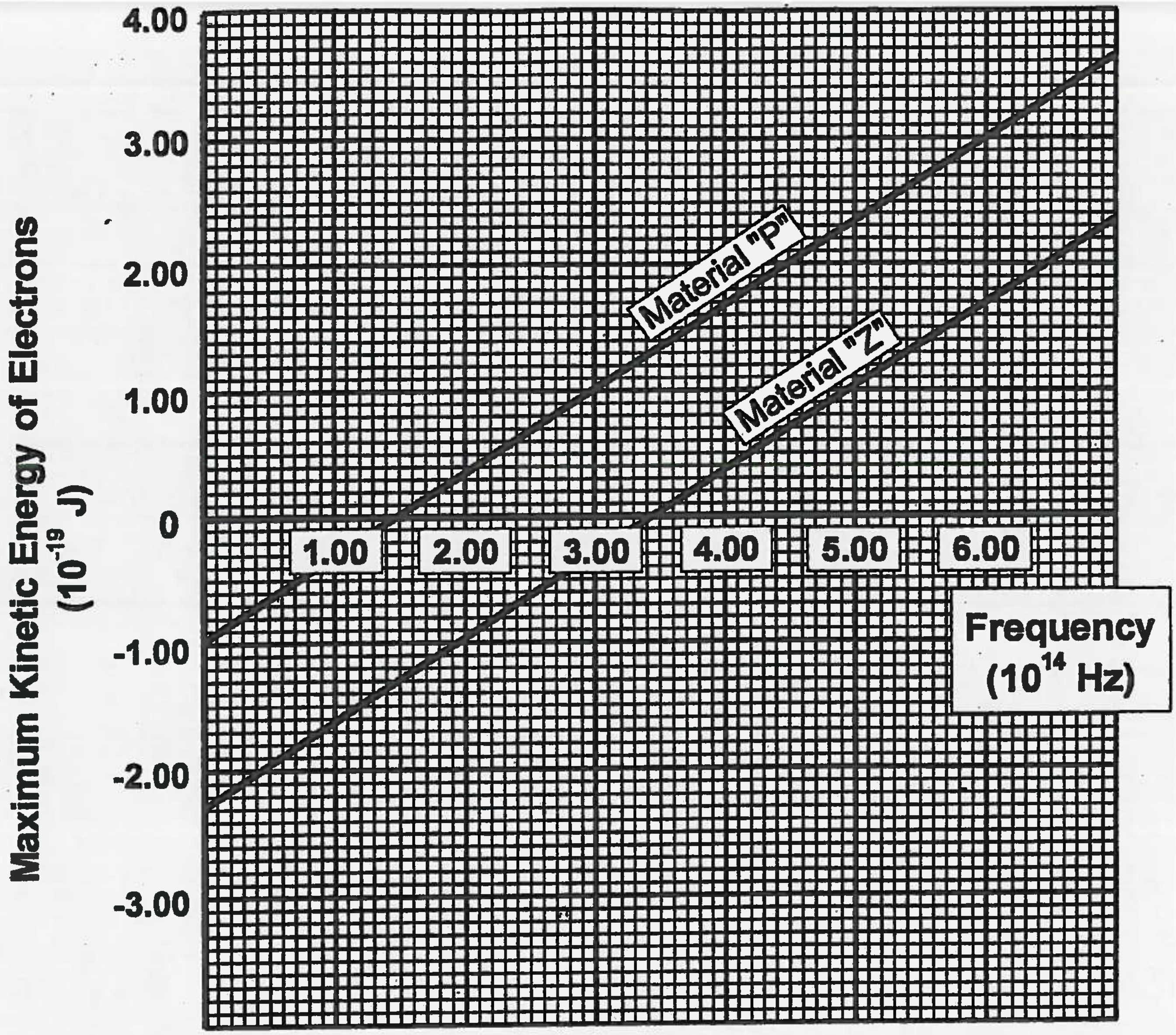
The graph below shows the maximum kinetic energy of an ejected electron plotted against the frequency of light for material "Z".



In an experiment, material "P" was bombarded with light of frequency 6.00×10^{14} Hz and the maximum kinetic energy of an ejected electron was 3.00×10^{-19} joules.

(a) Draw the line for material "P" on the graph above.
(b) Calculate Planck's constant using the graph.
(c) What is the least energy that a photon must have to eject an electron from material "P" ?
(d) Find the wavelength of the smallest energy photon which is able to eject an electron from material "P".
(e) If material "P" is bombarded with photons having a frequency of 2.50×10^{14} Hz, what is the maximum kinetic energy that an ejected electron could have ?

Solution:
(a)



(b)

$$h = \text{slope} = \frac{4.65 \times 10^{-19}\ \text{J}}{7.00 \times 10^{14}\ \text{Hz}}$$

$$= \underline{6.64 \times 10^{-34}\ \text{J.s}}$$

Note: It is difficult to read the graph to three significant digits. Thus there is some uncertainty about the third digit in this answer. The standard value of 6.63×10^{-34} J.s will be used for Planck's constant in parts (c), (d), and (e).

(c) $W = hf - E_k$

$= (6.63 \times 10^{[illegible]}\ J.s)(6.00 \times 10^{[illegible]}\ Hz) - 3.00 \times 10^{[illegible]}\ J$

$= 3.98 \times 10^{-19}\ J - 3.00 \times 10^{-19}\ J$

$= 0.98 \times 10^{-19}\ J$

$= \underline{9.8 \times 10^{-20}\ J}$

(d) $W = \dfrac{hc}{\lambda}$

$\lambda = \dfrac{hc}{W}$

$= \dfrac{(6.63 \times 10^{-34}\ J.s)(3.0 \times 10^{8}\ m/s)}{9.8 \times 10^{-20}\ J}$

$= \underline{2.0 \times 10^{-6}\ m}$

(e) $E_k = hf - W$

$= (6.63 \times 10^{-34}\ J.s)(2.50 \times 10^{14}\ Hz) - 9.8 \times 10^{-20}\ J$

$= 1.66 \times 10^{-19}\ J - 9.8 \times 10^{-20}\ J$

$= \underline{6.8 \times 10^{-20}\ J}$

Example 4:

Light with a wavelength of 3.9 x 10^{-7} m falls on a photoelectrode made of cesium which has a work function of 1.90 eV. The retarding potential is 0.60 V.

Find (a) the maximum kinetic energy (in joules) of an electron as it leaves the photoelectrode

(b) the maximum speed with which an electron reaches the collector plate.

Solution:

(a)

$$E_k = E_{ph} - W$$

$$= \frac{hc}{\lambda} - W$$

$$= \frac{(6.63 \times 10^{-34}\ \text{J.s})(3.0 \times 10^{8}\ \text{m/s})}{3.9 \times 10^{-7}\ \text{m}} - (1.90\ \text{eV})(1.6 \times 10^{-19}\ \text{J/eV})$$

$$= 5.10 \times 10^{-19}\ \text{J} - 3.04 \times 10^{-19}\ \text{J}$$

$$= 2.06 \times 10^{-19}\ \text{J}$$

$$= \underline{2.1 \times 10^{-19}\ \text{J}}$$

(b)

$$E_{k_f} = E_{k_i} - E_e$$

$$= E_{k_i} - qV$$

$$= 2.06 \times 10^{-19}\ \text{J} - (-1.6 \times 10^{-19}\ \text{C})(-0.60\ \text{V})$$

$$= 1.10 \times 10^{-19}\ \text{J}$$

$$E_{k_f} = \frac{1}{2} m v^2$$

$$v = \sqrt{\frac{2E_{k_f}}{m}}$$

$$= \sqrt{\frac{2(1.10 \times 10^{-19}\ \text{J})}{9.1 \times 10^{-31}\ \text{kg}}}$$

$$= \underline{4.9 \times 10^{5}\ \text{m/s}}$$