Ch 37: Early Quantum Theory and Models of the Atom

Blackbody Radiation, Photoelectric Effect, & Wave Nature of Matter

Objective:

I. Solve problems involving **Blackbody Radiation**

→ By using **Wien's Law** that relates the wavelength of radiation to an object's radiation

II. Solve problems involving the **Photoelectric Effect**

→ By identifying the **work function** W_0 of the material

III. Solve problems that relates waves and particles

→ By applying the **de Broglie wavelength** equation to find a particle's wavelength

Content Review:

I. Wien's Law

The peak (max intensity) wavelength λ of the thermal radiation emitted by an object at temperature T is given by

$$\lambda = \frac{2.9 \times 10^{-3}}{T}$$

II. Photoelectric Effect

The energy of a Photon is given by Planck's Law

$$E = h\,f = h\,\frac{c}{\lambda}$$

where f is the frequency of the photon and λ is the wavelength of the photon.

By Conservation of Energy, the "Photoelectric equation" is

$$\text{Incoming Energy} = \text{Outgoing Energy}$$
$$E_{\text{photon}} = KE + W_0$$

III. Wave Nature of Matter

The **de Broglie wavelength** is given by

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

Guided Practice (leader - student) [10mins]

Wien's Law

How hot is metal being welded if it radiates most strongly at $460\,\mathrm{nm}$

Solution

$T = 6300\,\mathrm{K}$

Group Activity (student - student) [10mins]

Photoelectric Effect

Light is incident on a metal. No current flows unless the wavelength is LESS than $520\,\mathrm{nm}$.

(a) What is the work function W_0 of this material?

(b) What is the stopping voltage required if light of wavelength $470\,\mathrm{nm}$ is used?

Solution

(a) $W_0 = 2.4\,\mathrm{eV}$

(b) $V = 0.25\,\mathrm{V}$

Group Activity (student - student) [10mins]

Wave Nature of Matter

Calculate the wavelength of a $0.23\,\mathrm{kg}$ ball traveling at $0.10\,\mathrm{m/s}$.

Solution

$\lambda = 2.9 \times 10^{-32}\,\mathrm{m}$

An electron has a de Broglie wavelength $\lambda = 6.0 \times 10^{-10}\,\mathrm{m}$

(a) What is its momentum?

(b) What is its speed?

(c) What voltage was needed to accelerate it to this speed?

Solution

(a) $p = 1.1 \times 10^{-24}\,\mathrm{kg\,m/s}$

(b) $v = 1.2 \times 10^{6}\,\mathrm{m/s}$

(c) $V = 4.2\,\mathrm{V}$